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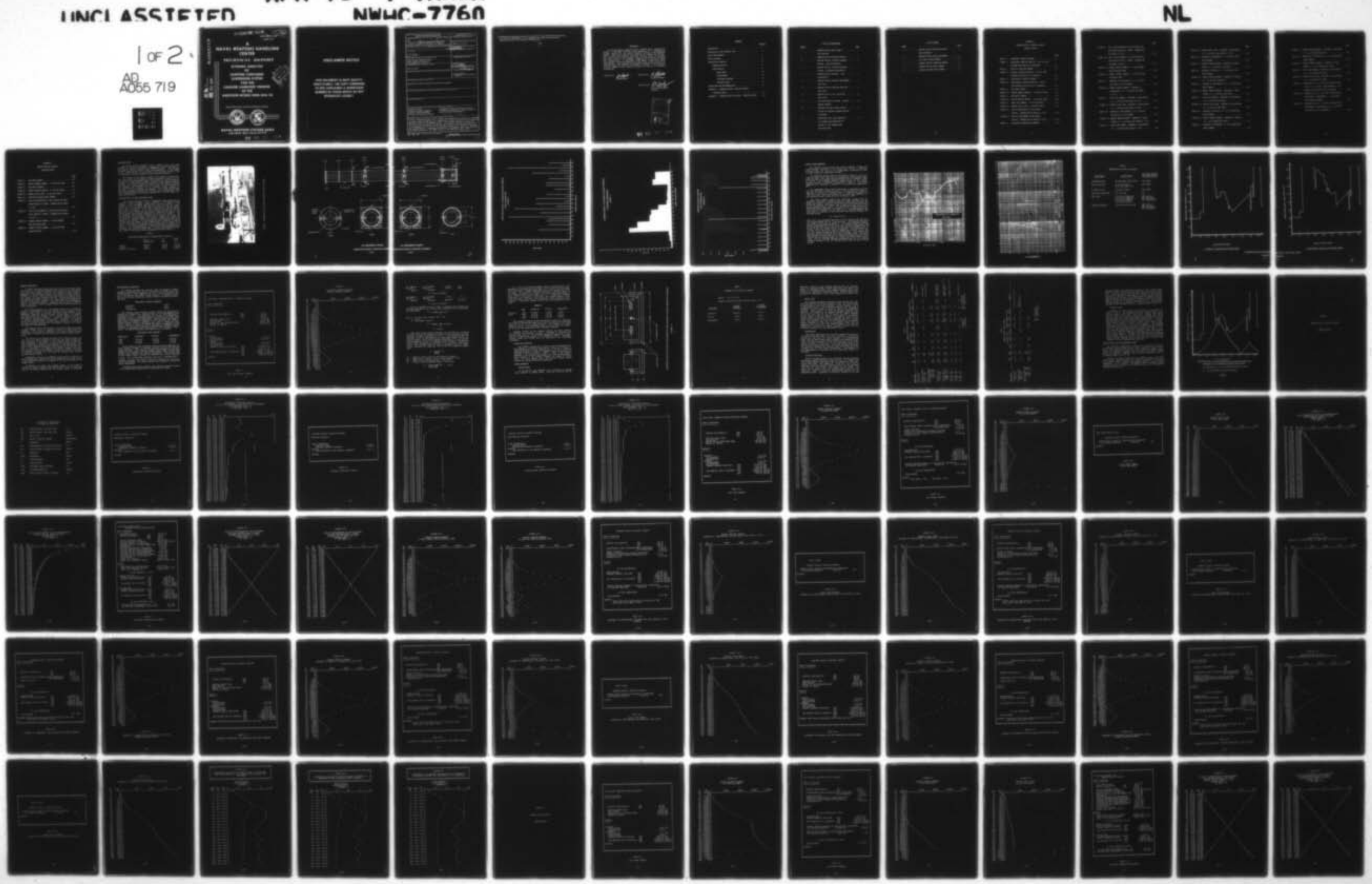

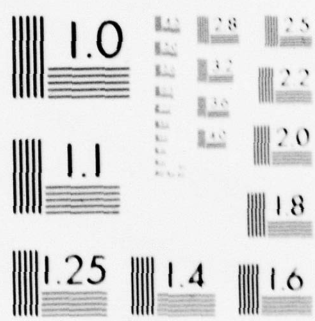
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NWHC REPORT 7760

1 APRIL 1978

A NAVAL WEAPONS HANDLING CENTER

TECHNICAL REPORT

DYNAMIC ANALYSIS OF SHIPPING CONTAINER SUSPENSION SYSTEM FOR THE CANISTER LAUNCHED VERSION OF THE HARPOON MISSILE RGM-84A-3A

NAVAL WEAPONS STATION EARLE
Colts Neck, New Jersey 07722

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 7760 (6)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Dynamic Analysis of Shipping Container Suspension System For the Canister Launched Version of the HARPOON Missile RGM-84A-3A		5. TYPE OF REPORT & PERIOD COVERED (9) Final rept.,
		6. PERFORMING ORG. REPORT NUMBER (14) NWHC-7760
7. AUTHOR(s) (10) Y. Trask		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Weapons Handling Center Naval Weapons Station Earle Colts Neck, N.J. 07722		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Same as above		12. REPORT DATE (11) 1 April 1978
		13. NUMBER OF PAGES (12) 97p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dynamic Analysis
Isolation Systems Parameters
Canister Launched HARPOON
Shipping and Storage Container
Packaging Configuration Using Isolators
Configuration adequately protects weapon in specified shock environments.

This center

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Naval Weapons Handling Center, WPNSTA Earle, conducted an analysis to determine isolation system parameters for a shipping and storage container for the canister-launched version of the HARPOON missile. This report presents the details of the analysis and information concerning the predicted shock and vibration forces on the packaged item as well as the container caused by the hazards of handling and transportation. A packaging configuration is presented, which uses isolators previously approved for the ASROC version of the HARPOON missile. This → over

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ABSTRACT

The Naval Weapons Handling Center, WPNSTA Earle, conducted an analysis to determine isolation system parameters for a shipping and storage container for the canister launched version of the HARPOON missile. This report presents the details of the analysis and information concerning the predicted shock and vibration forces on the packaged item as well as the container caused by the hazards of handling and transportation. A packaging configuration is presented, which uses isolators previously approved for the ASROC version of the HARPOON missile. This configuration adequately protects the weapon in its specified shock and vibration environments; therefore, it is recommended that ASROC version approved isolators be used in the proposed configuration.

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HARPOON MISSILE CANISTER

COMPUTER OUTPUT

INTRODUCTION

The Naval Weapons Handling Center, WPNSTA Earle, has been assigned the task of developing a shipping and storage container for the canister launched version of the HARPOON missile. The principal technical sub-tasks involved in such a development are: (1) the design of the isolation system, (2) the design of the container structure, and (3) subsequent test and evaluation of the prototype container.

The design of the isolation system is the subject of this report. The output of the report consists of design parameters, which are to be used by shock mount manufacturers and container structural designers, presented as results from the NWHC container design computer program package. The design parameters presented are the natural frequency and damping of the isolation system, the location of shock mounts and the reaction loads developed by the isolation system's response to specified shock and vibration environments. The design specifications that these parameters address are contained in two specifications, XAS 2381 (HARPOON Missile Environment Specification) and XAS 3894 (Container Specification).

DESCRIPTION OF THE PACKAGED ITEM

The canister launched version of HARPOON being loaded into its canister is shown in Figure 1 and a schematic of the missile/canister assembly in the packaging configuration is shown in Figure 2. The missile air scoop is placed down and the wings and fins are folded. Three shoes are located on each side of the weapon at missile stations 88.12, 166.0, and 189.12. A fire thru restraint bolt and an explosive inadvertent fire restraint bolt are located at missile station 192.13. The missile weighs 1515.18 pounds distributed as illustrated in Figure 3 and has stiffness characteristics presented by the EI plot, Figure 4. The overall length of the missile is 182.2 inches, diameter 13.5 inches and the missile is supported within the canister on launch rails running the length of the canister. The forward missile and forward booster shoes interface with the canister at the stacking frames (CS 80.52, CS 158.39). The overall length of the canister is 189.5 inches and the diameter 23.50 inches. The canister weighs 490.30 pounds distributed as illustrated in Figure 5. The stacking frames are 25.90 inches high (excluding stacking guide pin) and 26.10 inches wide. The mass properties of the missile, canister and missile/canister assembly are listed in Table 1.

Table 1

HARPOON Missile/Canister Assembly Mass Properties

	I_{pitch} (in-lb-sec^2)	CG (MS)	Weight (lb)
Missile	10240.8	104.88	1515.18
Canister	4320.0	108.70	490.30
Missile in Canister	14575.8	105.82	2005.48

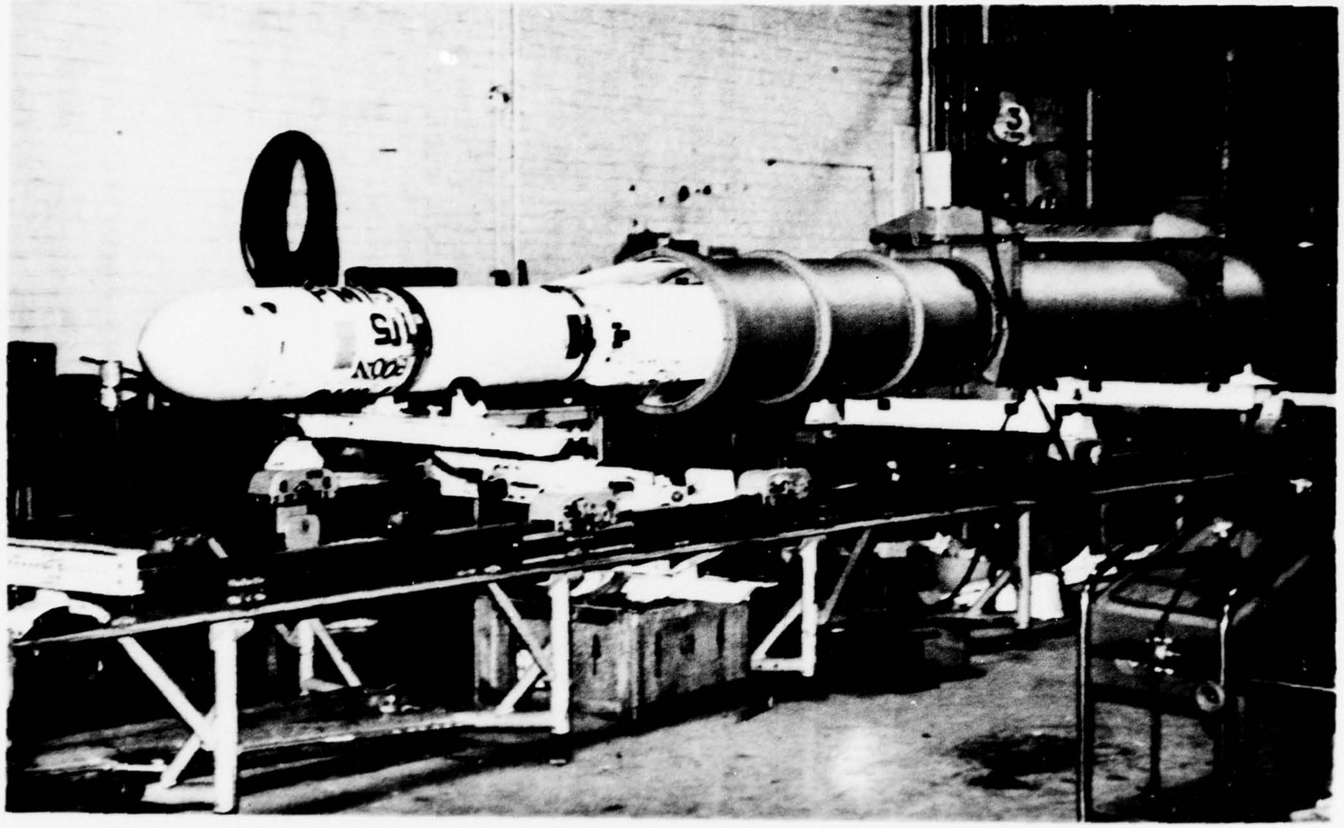
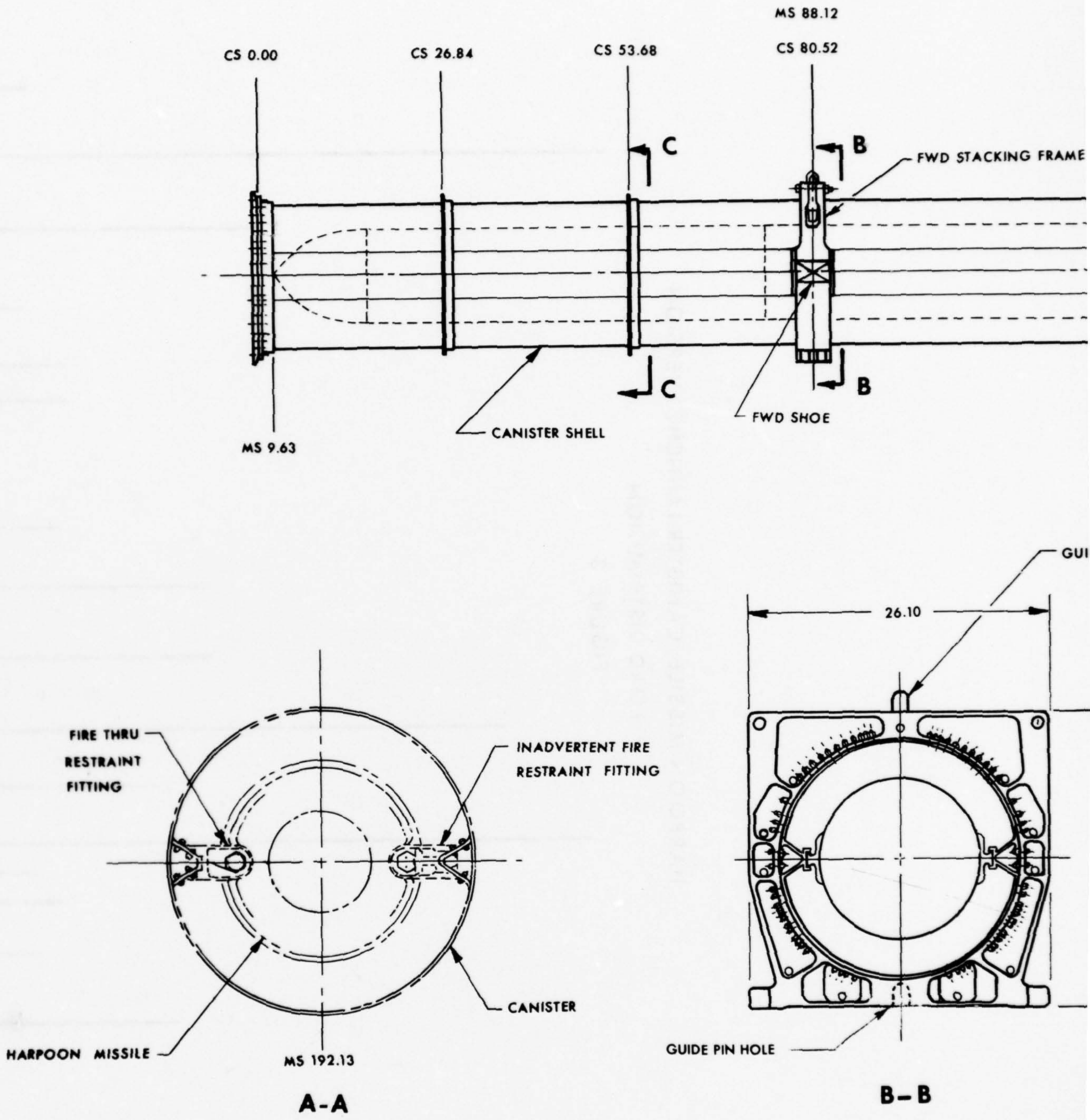


FIGURE 1. HARPOON MISSILE BEING LOADED INTO CANISTER



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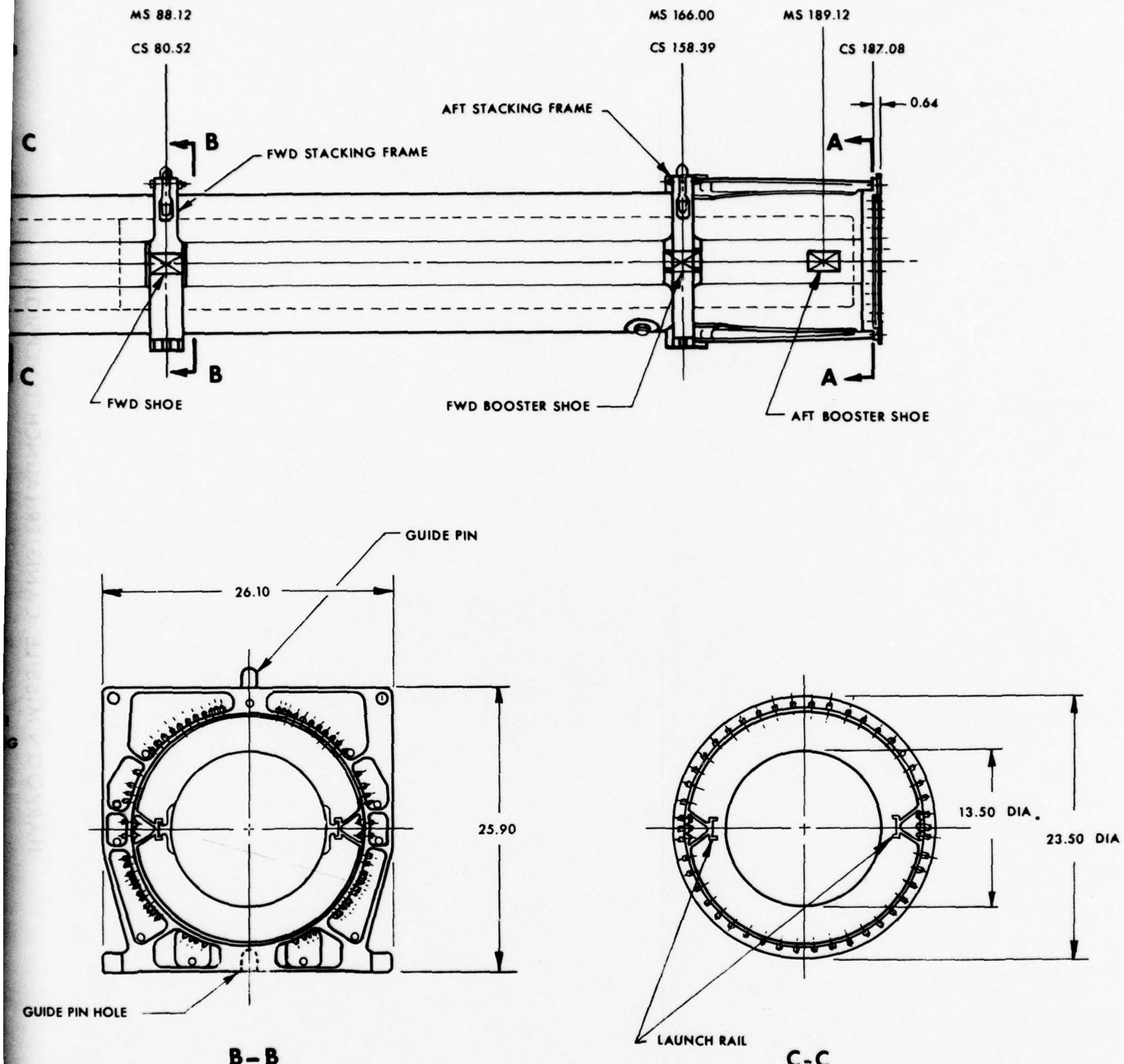
HARPOON MISSILE/CANISTER AS

FIGURE 2



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HARPOON MISSILE/CANISTER ASSEMBLY

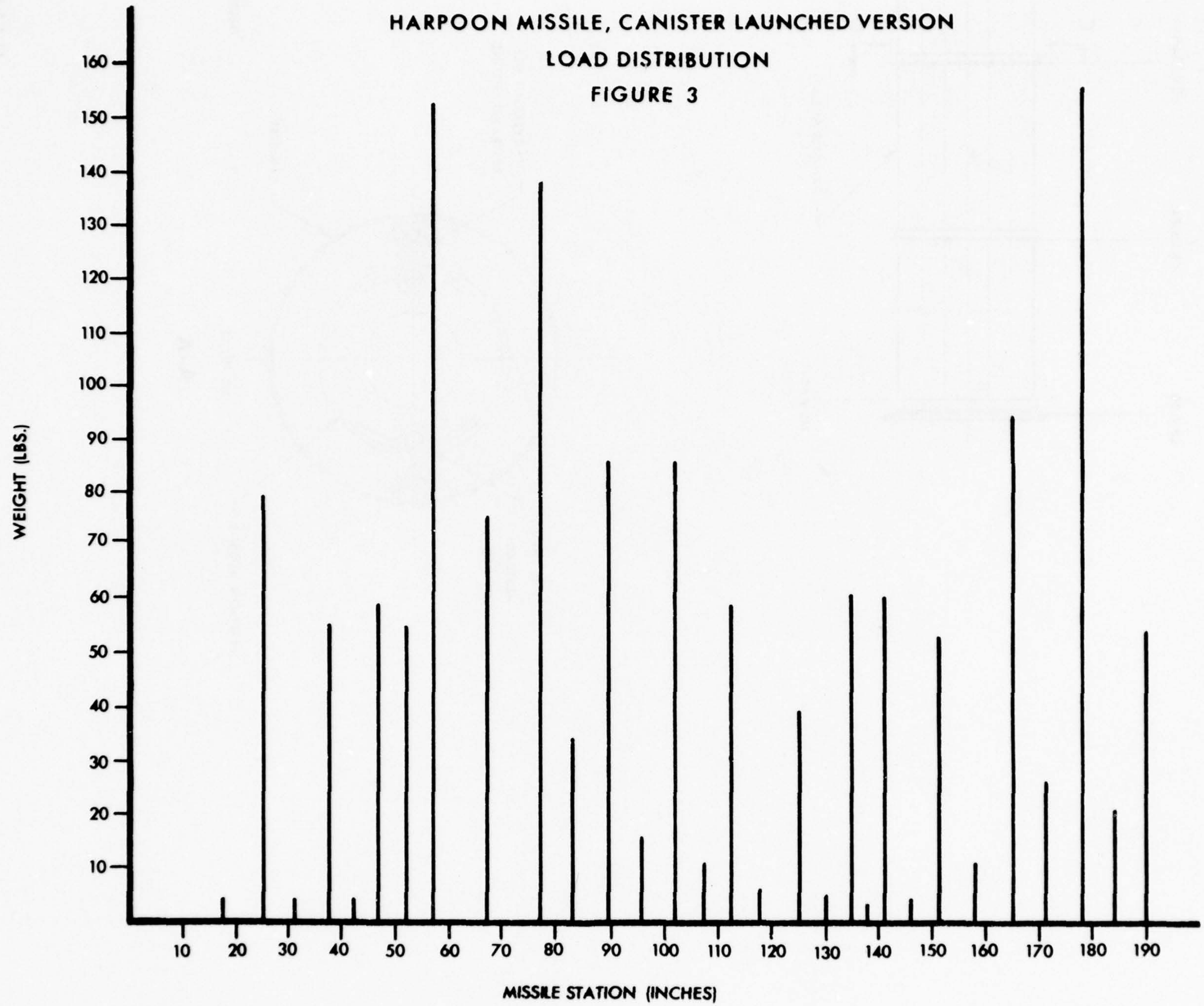
FIGURE 2

2

HARPOON MISSILE, CANISTER LAUNCHED VERSION

LOAD DISTRIBUTION

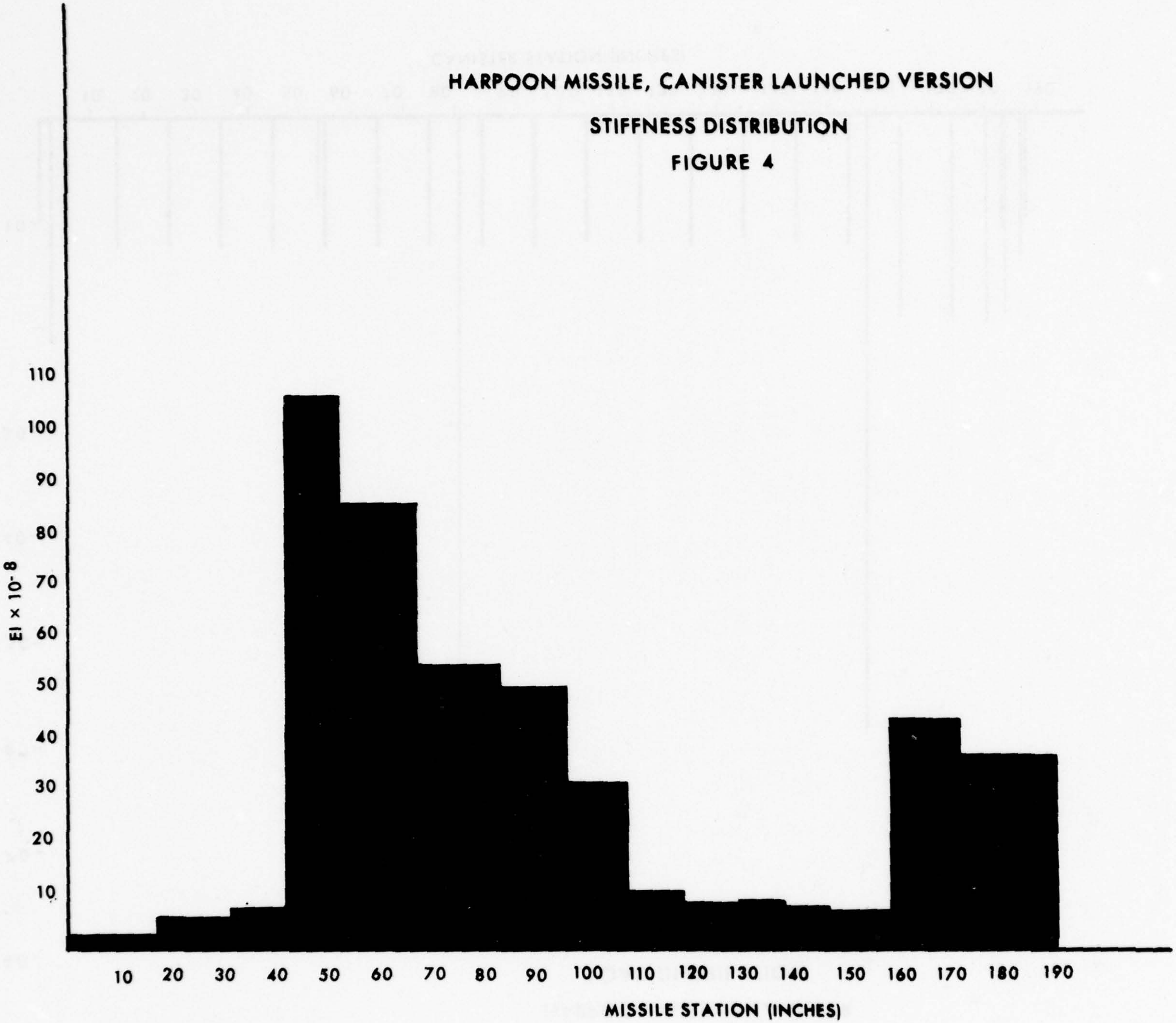
FIGURE 3



HARPOON MISSILE, CANISTER LAUNCHED VERSION

STIFFNESS DISTRIBUTION

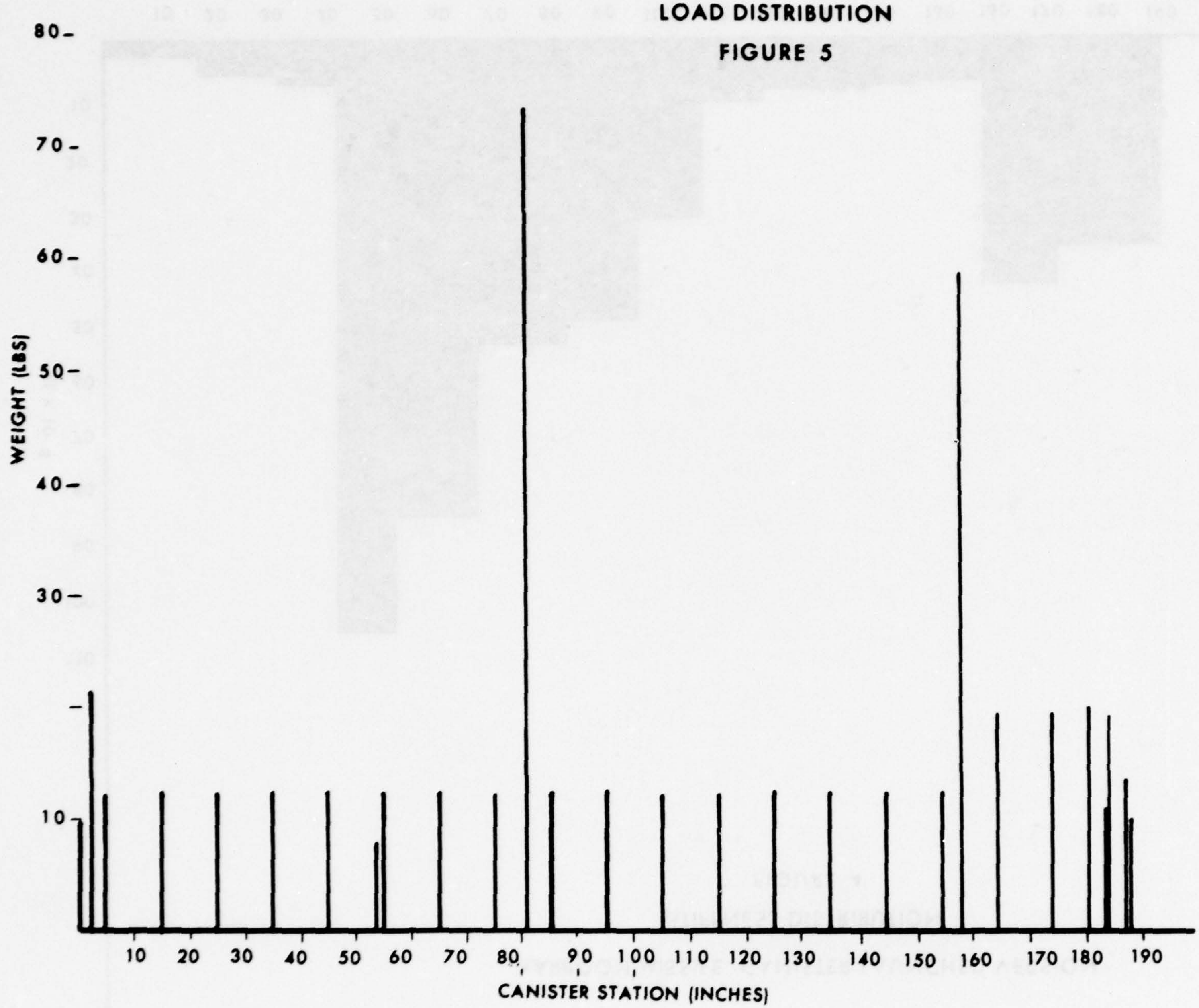
FIGURE 4



HARPOON MISSILE CANISTER

LOAD DISTRIBUTION

FIGURE 5



DESIGN REQUIREMENTS

The isolation system design must satisfy shipping, storage and rough handling requirements. The design must be able to withstand specified truck, rail, ship and air transportation environments as well as rough handling at temperature extremes.

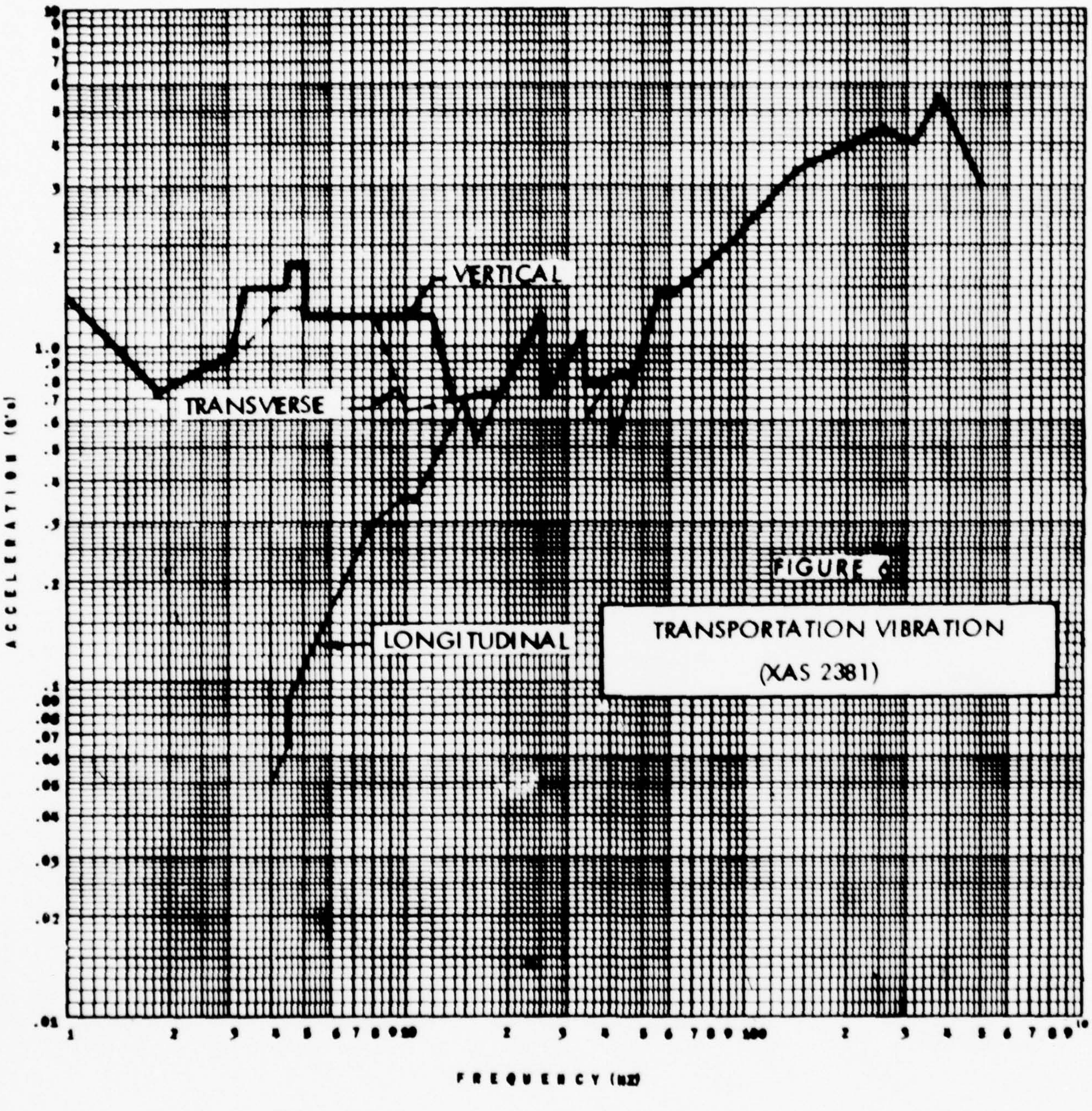
The HARPOON missile vibration environment, Figure 6, is the envelope of truck, rail, ship and air transportation environments taken from XAS 2381, with agreed upon modifications in the frequency range of 5-12 Hz. The vibration fragility (design levels) for the canister launched version of HARPOON is presented in Figure 7. The design temperature for vibration is specified to be normal room temperature, 70°F.

The HARPOON missile shock environment as extracted from XAS 2381 and XAS 3894 is listed in Table 2. The containerized weapon is expected to survive the specified inputs at temperature extremes of -20°F and 140°F, with the exception of the near miss eligibility test and shipboard shocks, which are to be performed at 70°F.

The shock analysis utilizes the acceleration design levels for HARPOON components, bending moment and axial load limits for the missile and canister structures and interface reaction limits between the missile and canister, and canister and container as the survival criteria for the missile/canister system. The acceleration design level for the HARPOON missile components is specified as a 42 g terminal peak sawtooth shock of duration not less than 25 ms. Bending moments and axial loads are combined to yield equivalent axial loads according to the following formula:

$$PE = (2/R)\ M + PA$$

where PE is the equivalent axial load, R is the radius of the item, M is the bending moment and PA is the axial load. The allowable equivalent axial loads are presented in Figure 8. The vertical interface locations between the missile and canister are at the canister stacking frames, MS 88.12 and MS 166.0 and at MS 189.12 with specified allowable loads of 18,200; 15,600 and 12,800 pounds respectively. The inadvertent fire restraint bolt at MS 192.13, used for longitudinal restraint of the weapon, has a load carrying capacity of 23,200 pounds. The canister shell maximum allowable equivalent axial load is 244,000 pounds. The maximum allowable vertical loads for the canister/container interfaces at the forward and aft stacking frames are 101,600 and 24,400 pounds respectively, and the maximum allowable longitudinal load for the canister/container interface at the aft stacking frame guide pin hole is 45,000 pounds.



VERTICAL
TRANSVERSE
LONGITUDINAL
FIGURE 6
TRANSPORTATION VIBRATION
(XAS 2381)
ACCELERATION (G's)
FREQUENCY (HZ)

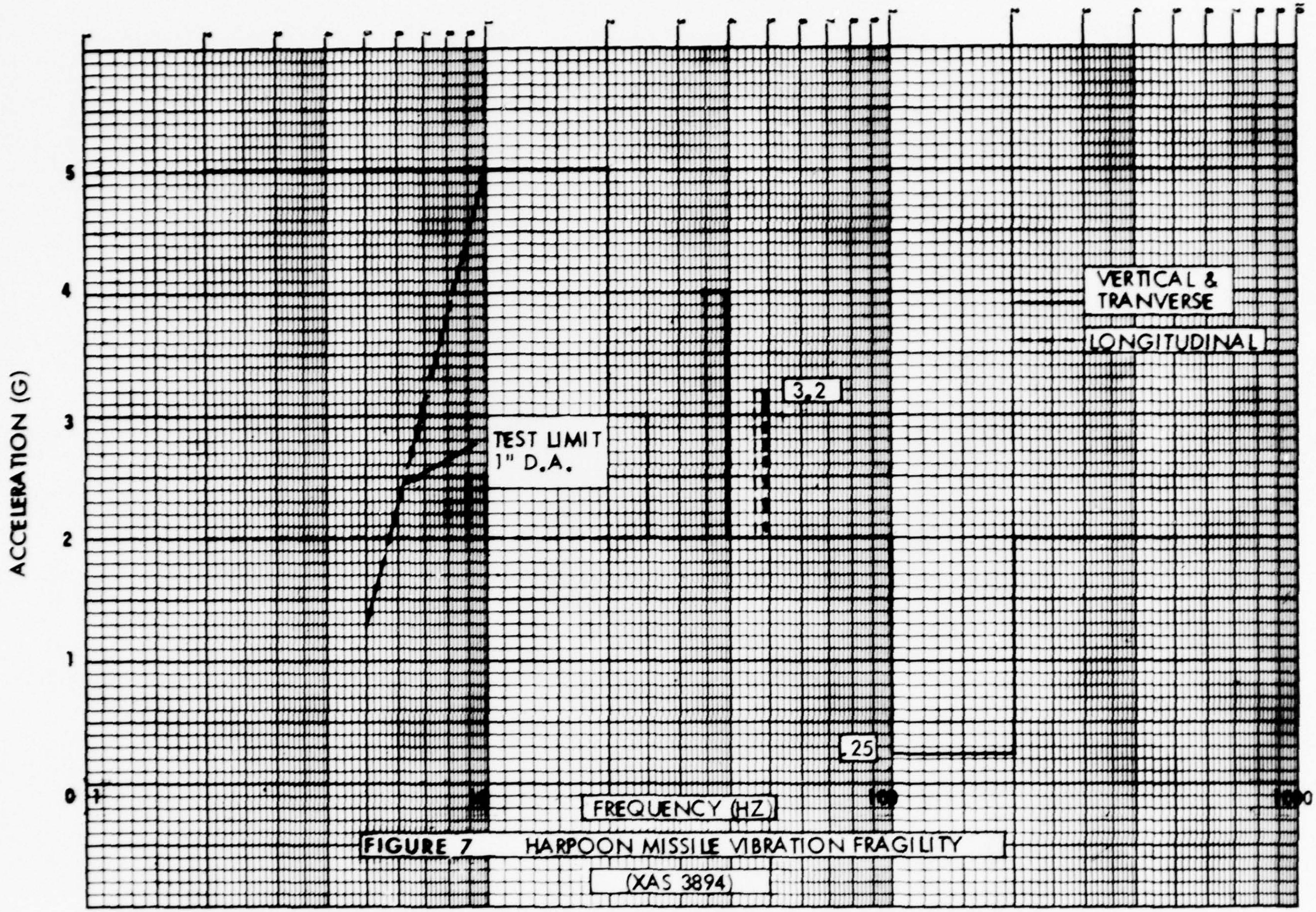
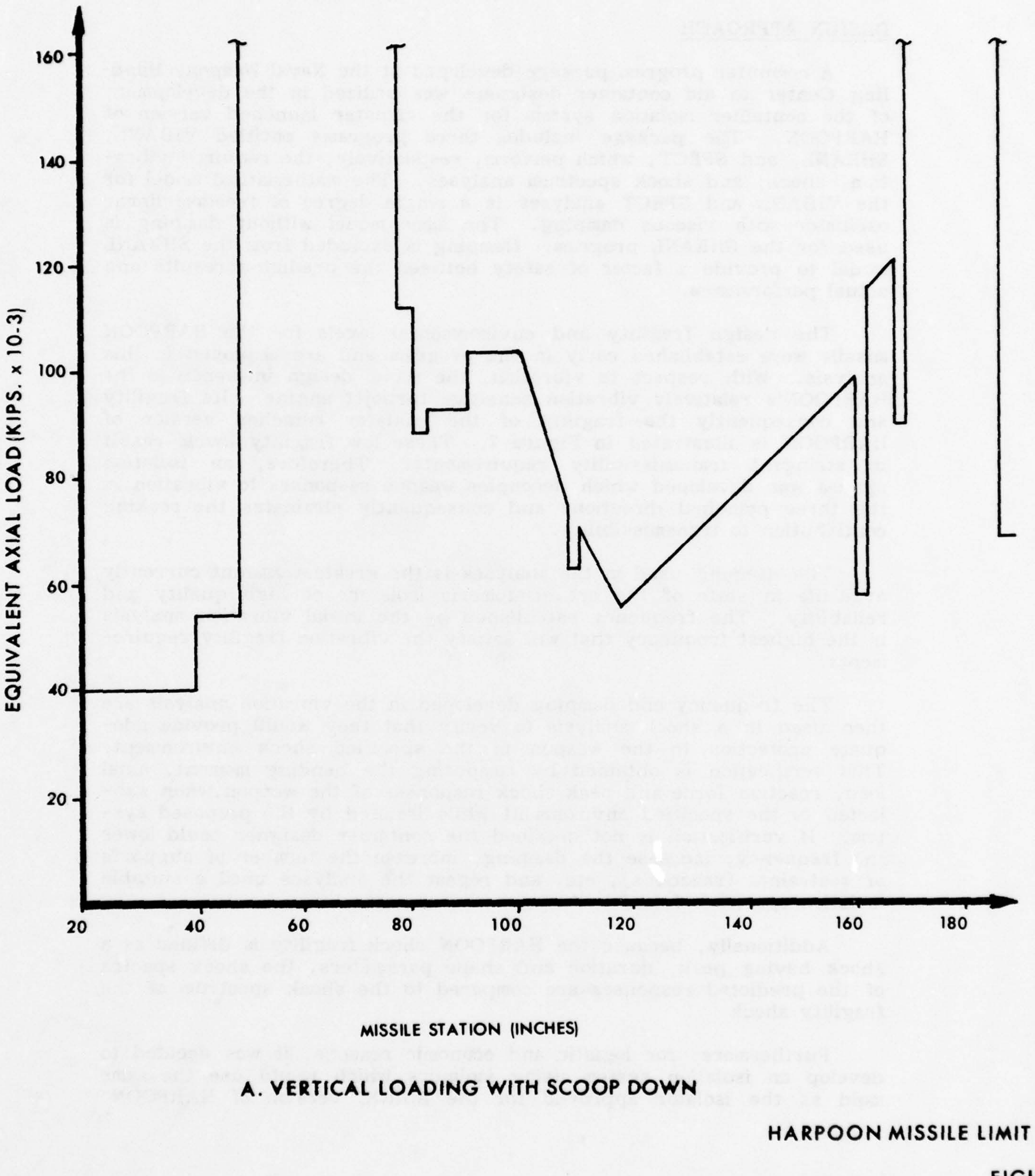


FIGURE 7 HARPOON MISSILE VIBRATION FRAGILITY
(XAS 3894)

TABLE 2

HARPOON Missile Shock Environment

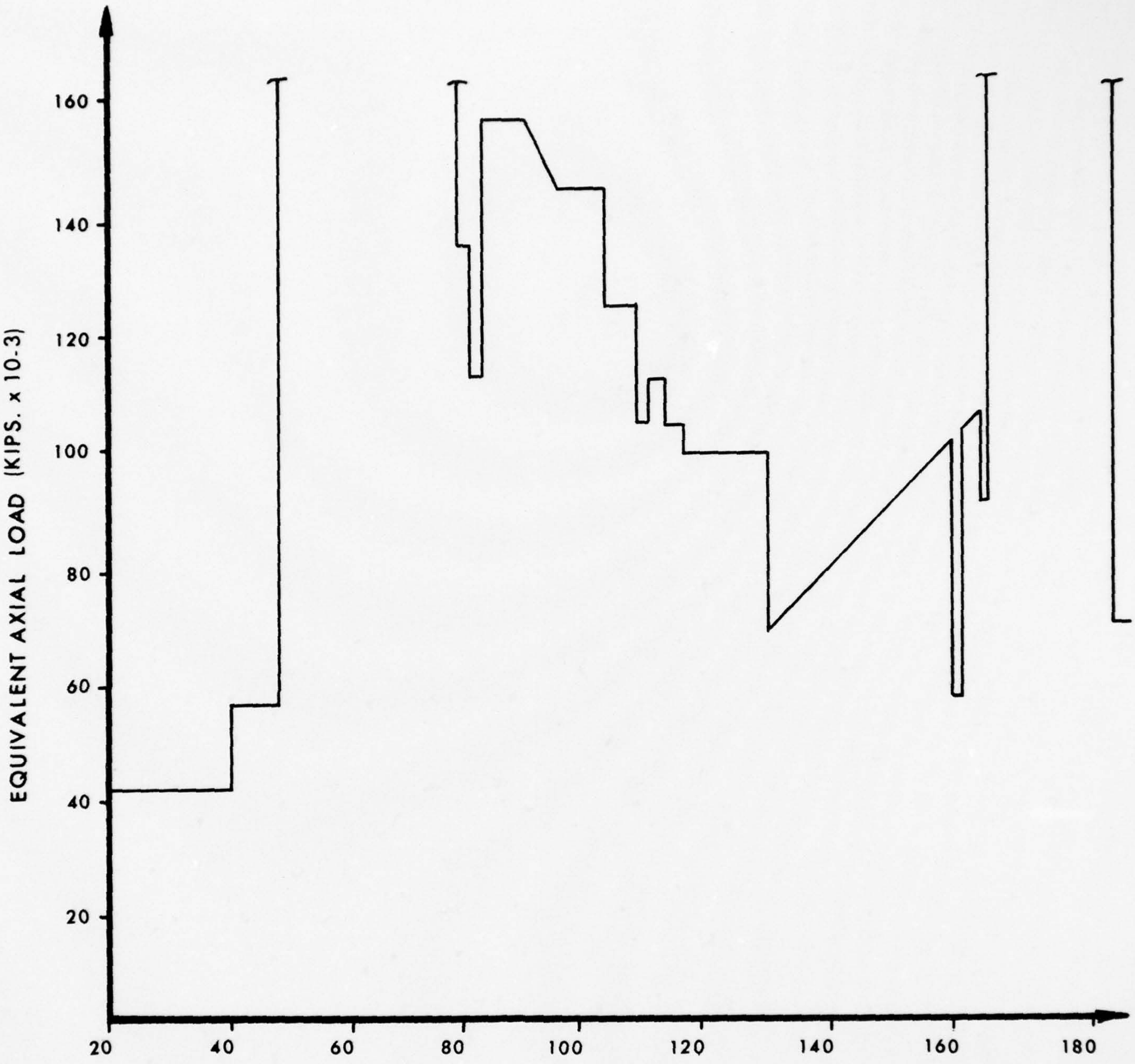
SHOCK EVENT	SPECIFICATION	APPLICABLE TEMPERATURE AND DIRECTION
Storage/Handling	18" Rotational Corner Drop	-20^{o}, 140^{o}F
Railcar Coupling	10 fps End Impact 25 g, 25 ms half sine	-20^{o}, 140^{o}F
Transfer at Sea	10 fps End Impact	-20^{o}, 140^{o}F
Near Miss Eligibility	18" Flat Drop	70^{o}F
Ship Shock	15 g, 35 ms Trapezoid* 9 g, 35 ms Trapezoid* 6 g, 35 ms Trapezoid* *10 ms Rise & Decay	70^{o}F Vertical 70^{o}F Transverse 70^{o}F Longitudinal
Shipboard Handling	15 g, 11-18 ms half sine	70^{o}F Vertical 70^{o}F Transverse 70^{o}F Longitudinal



A. VERTICAL LOADING WITH SCOOP DOWN

HARPOON MISSILE LIMIT EQUIV

FIGURE 8



B. TRANSVERSE LOADING WITH SCOOP DOWN

MIT EQUIVALENT AXIAL LOAD

FIGURE 8

2

DESIGN APPROACH

A computer program package developed at the Naval Weapons Handling Center to aid container designers was utilized in the development of the container isolation system for the canister launched version of HARPOON. The package includes three programs entitled VIBANL, SHKANL, and SPECT, which perform, respectively, the required vibration, shock, and shock spectrum analyses. The mathematical model for the VIBANL and SPECT analyses is a single degree of freedom linear oscillator with viscous damping. The same model without damping is used for the SHKANL program. Damping is excluded from the SHKANL model to provide a factor of safety between the predicted results and actual performance.

The design fragility and environmental levels for the HARPOON missile were established early in the program and are employed in this analysis. With respect to vibration, the major design influence is the HARPOON's relatively vibration sensitive turbojet engine. Its fragility and consequently the fragility of the canister launched version of HARPOON is illustrated in Figure 7. These low fragility levels result in stringent transmissibility requirements. Therefore, an isolation system was developed which decouples weapon responses to vibration in the three principal directions and consequently eliminates the rocking contribution to transmissibility.

The damping used in the analyses is the greatest amount currently available in state of the art elastomeric isolators of high quality and reliability. The frequency established by the initial vibration analysis is the highest frequency that will satisfy the vibration fragility requirements.

The frequency and damping developed in the vibration analysis are then used in a shock analysis to verify that they would provide adequate protection to the weapon in the specified shock environment. This verification is obtained by computing the bending moment, axial load, reaction force and peak shock responses of the weapon when subjected to the specified environment while isolated by the proposed system. If verification is not obtained the container designer could lower the frequency, increase the damping, increase the number of supports or restraints (reactions), etc. and repeat the analyses until a suitable isolation system is found.

Additionally, because the HARPOON shock fragility is defined as a shock having peak, duration and shape parameters, the shock spectra of the predicted responses are compared to the shock spectrum of the fragility shock.

Furthermore, for logistic and economic reasons, it was decided to develop an isolation system using isolators which would use the same mold as the isolator approved for the ASROC version of HARPOON.

DISCUSSION OF RESULTS

The VIBANL program was executed using the maximum available damping of economical shock mounts, 13 percent of critical, and a compression/tension to shear stiffness ratio of 4:1, which results from the use of the mold for the ASROC version isolators. A satisfactory solution to the vibration problem was found in which the predicted frequencies were:

PRELIMINARY VIBRATION FREQUENCY

Transverse	19 Hz
Vertical	10 Hz
Longitudinal	10 Hz

The isolation system natural vibration frequencies generated by VIBANL were divided by a conversion factor of 1.1 to approximate shock frequencies at 70°F. This adjustment accounts for the nonlinearity of elastomeric mounts of comparable elastomer, stiffness and shape when subjected to shock induced displacement. Several of the shock requirements apply to temperature extremes of -20°F and 140°F, see Table 2. Nominal thermal stiffness coefficients were used to modify the 70°F shock frequency to account for temperature effects on elastomeric shock mounts. The 70°F shock frequency is multiplied by coefficients of $\sqrt{1.3}$ and $\sqrt{0.9}$ to approximate shock frequencies at -20°F and 140°F, respectively. The shock frequencies were computed to be as follows:

PRELIMINARY SHOCK FREQUENCY

Temperature	Transverse	Vertical	Longitudinal
-20°F	19.69 Hz	10.36 Hz	10.36 Hz
70°F	17.27 Hz	9.09 Hz	9.09 Hz
140°F	16.38 Hz	8.62 Hz	8.62 Hz

These isolation system parameters were then used in SHKANL, the shock analysis program, to determine whether they provide adequate shock protection. The proposed isolation system failed the flat drop analysis in that reaction load and bending moment limits at the forward support were exceeded, see Table 3 and Figure 9. The reaction load at the forward support exceeded the allowable load by more than 5500 pounds. The corresponding equivalent axial load, $(.296)(388.6\text{x}10^3) = 115.0\text{x}10^3$, exceeded the $91.0\text{x}10^3$ inch-pound allowable by more than 24,000 inch-pounds. The shock frequency was decreased to satisfy the shock requirements.

Assuming linear elastic deflection and using the computed results, a new vertical shock frequency for consideration was found.

FLAT DROP- HARPOON MISSILE CANISTER VERSION

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	88.12	
	CTR	166.00	
	AFT	189.12	
VERTICAL SHOCK FREQ		9.09	HZ
DROP HEIGHT		18.00	INS
WEIGHT OF THE CONTAINER SHELL		500.00	LBS
WEIGHT OF CRADLE		917.50	LBS

RESULTS

PRIMARY-			
DISPLACEMENT		2.19	INS
DECELERATION		18.45	G
REBOUND-			
DISPLACEMENT		0.37	INS
DECELERATION		3.15	G
DYNAMIC SUPPORT REACTIONS	FWD	23713.21	LBS
	CTR	-1719.87	LBS
	AFT	5967.17	LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-388607.12	IN-LBS
	CTR	70692.14	IN-LBS
	AFT	-883.90	IN-LBS

REMARKS

TABLE 3

FLAT DROP FAILURE SUMMARY

FIGURE 9

FLAT DROP ANALYSIS FAILURE
DYNAMIC BENDING MOMENTS

Axis: 0, 98000, 196000, 294000, 392000

IS IN	MOM IN-LBS
0	0.
5	0.
10	0.
15	0.
20	-194.
25	-761.
30	-8379.
35	-16212.
40	-25975.
45	-39135.
49	-55930.
54	-77225.
59	-106573.
64	-144283.
69	-185319.
74	-229939.
79	-281903.
84	-339869.
88	-388607.
94	-327701.
99	-279531.
104	-235076.
109	-195585.
114	-158007.
119	-124635.
124	-91868.
129	-61981.
134	-33151.
139	-8407.
144	11777.
148	28820.
153	43936.
158	55983.
163	67098.
166	70692.
173	60877.
178	51373.
183	28679.
189	-884.
193	-0.

$$\frac{\text{g's computed reaction}}{\text{computed}} = \frac{\text{g's allowable reaction}}{\text{allowable}} \qquad \frac{18.45}{23713.21} = \frac{G}{18200}$$

$$G = 14.16 \text{ g allowable}$$

$$\frac{\text{g's computed bending}}{\text{computed}} = \frac{\text{g's allowable bending}}{\text{allowable}} \qquad \frac{18.45}{388.6\text{x}10^3} = \frac{G}{307.4\text{x}10^3}$$

$$G = 14.59 \text{ g allowable}$$

Given an allowable g-level, 14.16g - satisfying both reaction and bending requirements, the vertical shock frequency can be found using the relationship.

$$F^2 = \frac{4.89845 \quad [(G-1)^2-1]}{H}$$

where F = vertical shock frequency (Hz), 70°F
G = g-level
H = drop height (inches)

$$F^2 = \frac{4.89845 \quad [(14.16-1)^2-1]}{18}$$

$$F = 6.85 \text{ Hz}$$

This 70°F vertical shock frequency was converted to a vertical vibration frequency by applying the inverse of the previously discussed procedure to yield a frequency of 7.54 Hz. It was determined that this frequency could be approximated by using eight ASROC version approved isolators, which would eliminate development costs and provide interchangeability as well as eliminating tooling charges. Considering a total of eight mountings per container as in the ASROC version containers, the resulting frequency can be determined from the ASROC version frequency by using the ratio of the two suspended weights alone.

$$Fc = \left[\frac{Wa}{Wc}\right]^{\frac{1}{2}} Fa$$

Fc = Canister version isolator, 70°F vibration frequency
Fa = ASROC version isolator, 70°F vibration frequency -10 Hz
Wa = ASROC version suspended weight - 1365.08 lbs.
Wc = Canister version suspended weight - 2432.68 lbs.

$$Fc = \left[\frac{1365.08}{2432.68}\right]^{\frac{1}{2}}(10) = 7.49 \text{ Hz}$$

In a center of gravity mounting system as proposed here, the mountings are primarily loaded in shear in the vertical as well as longitudinal directions, yielding longitudinal and vertical frequencies which are equal. The transverse vibration frequency is directly related to the vertical frequency by the square root of the compression/tension to shear stiffness ratio which in this case is 4.0. Using these vibration frequencies, the vibration to shock factor and thermal stiffness coefficients previously presented, the appropriate shock frequencies were computed. A frequency summary for this second consideration is given below.

FREQUENCY

	Temp	Transverse	Vertical	Longitudinal
Vibration	70°F	14.98 Hz	7.49 Hz	7.49 Hz
Shock	-20°F	15.52 Hz	7.76 Hz	7.76 Hz
	70°F	13.62 Hz	6.81 Hz	6.81 Hz
	140°F	12.92 Hz	6.46 Hz	6.46 Hz

This proposed isolation system configuration, Figure 10, represents an isolation system having mount elastic centers located in the horizontal plane of the CG of the isolated element. The isolators are loaded primarily in shear in the longitudinal and vertical directions and primarily in tension and compression in the transverse direction.

Computer outputs for the complete vibration and shock analyses are presented in Appendices A and B. Appendix A represents the analysis with respect to the HARPOON missile and Appendix B represents the analysis with respect to the HARPOON canister. Significant analysis results and problem areas are discussed in the succeeding paragraphs:

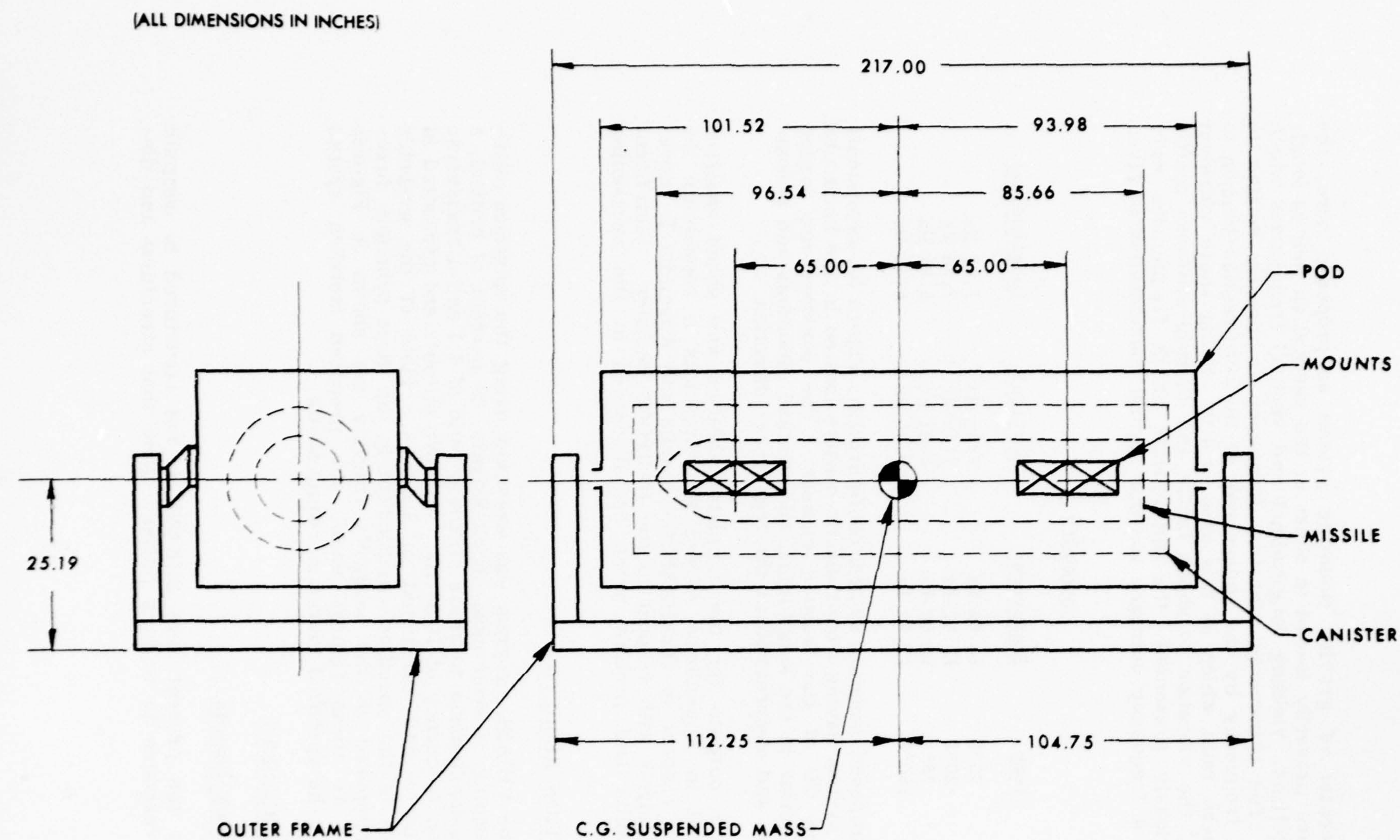
VIBRATION RESULTS

The VIBANL program was executed using the maximum available damping of economical shock mounts, 13 percent of critical, a compression/tension to shear stiffness ratio of 4:1 and a transverse vibration frequency of 14.98 Hz. VIBANL outputs are presented in Appendix A and are listed in Table 4. Plots of the weapon's response to the specified environment in the three principle directions compared to the weapon's fragility are shown in Figures A1-A3. As these figures show, the proposed isolation system satisfies the specified vibration requirements.

SHOCK RESULTS

Shock Results

At the present time SHKANL is not structured to compute shock response to uniform pulses. Note that structural and dis-



PROPOSED ISOLATION SYSTEM CONFIGURATION FOR CANISTER LAUNCHED VERSION OF HARPOON

FIGURE 10

TABLE 4

HARPOON Missile Vibration Summary

Damping = 13% of critical

Compression/Tension to Shear Stiffness Ratio = 4:1

DIRECTION	NATURAL FREQUENCY	RESPONSE AT RESONANCE
Transverse	14.98 Hz	2.78 g
Vertical	7.49 Hz	4.97 g
Longitudinal	7.49 Hz	1.03 g

placement responses to the specified uniform pulses are computed using the existing SHKANL routines (flat drop, side impact, end impact) by computing pseudo drop heights/velocities which would result in the appropriate deceleration levels. SHKANL outputs are presented in Appendices A and B and summarized in Tables 5 and 6.

Shock Level

The maximum predicted deceleration levels in the three primary directions are the 19.09 g response to the -20°F forward edge rotational drop in the vertical direction, 12.68 g response to the 9 g trapezoidal shock in the transverse direction and the 15.51 g response to the 25 g half sine shock at -20°F in the longitudinal direction. Shock spectra of these deceleration responses were generated and compared to the weapon's allowable shock spectrum (42 g, not less than 25 ms TPS) using the SPECT program. Velocity shocks (drops and impacts) were assumed to be half sine shocks having a duration equal to one-half the natural shock period of the isolation system in the applicable direction. Acceleration time histories were run for the responses to acceleration shocks (specified by half sine or trapezoidal shocks) and the digitized output was used in the SPECT program. The spectrum comparisons, presented as Figures A25-A27, indicate that the predicted responses are within specification levels.

Displacement

The largest displacements in the three primary directions are 3.14 inches vertically down, 0.51 inches vertically up, 3.06 inches forward and aft, and 0.67 inches laterally. The displacements result from the 140°F forward edge rotational drop (computed at MS 9.63), the 18 inch flat drop, the 25 g half sine shock in the longitudinal direction at 140°F and the 9 g trapezoidal shock in the transverse direction respectively. The mount spacing (130 inches) was selected to maintain the required sway space within the levels resulting from the other shock requirements. The magnitude of the displacements is reasonable for the configuration under consideration.

Structural Response

Weapon bending moments and axial loads are the structural response parameters addressed in this analysis. The design levels for bending moments and axial loads are combined as limit equivalent axial loads. The formula $PE = (2/R)\, M + PA$ is used to determine equivalent axial load response where PE is the equivalent axial load, R is the radius (6.75 inches for the missile, 11.75 inches for the canister), M is the bending moment and PA is the axial load. Figure 8 shows the design levels specified for the HARPOON Missile. Application of the above equation to the peak

TABLE 5

HARPOON MISSILE SHOCK SUMMARY

SHOCK EVENT	DEC (G)	DSP (IN)	REACTION (KIPS) MS 88.12	MS 166.0	MS 189.12	MS 192.13	BENDING MOMENTS (IN-KIPS) MS 88.12	MS 166.0	MS 189.12	MS 192.13	REMARKS
Flat Drop (18")											Rebound
6.41 Hz 70°F.	14.09	2.98	18.1	-1.3	4.6		-296.8	54.0	-0.7		2.40g, 0.51 in.
End Impact (10fps)											
6.46 Hz 140°F		2.96									
7.76 Hz -20°F	15.14	2.46	1.2	5.9	-5.7	22.9*	- 21.1	-0.5	131.9	131.9	*Axial Reaction
Rotational Edge Drop											130" Mount Spacing
(18") 6.46 Hz FWD		3.14									
140°F. AFT		3.07									
7.76 Hz FWD	19.09	3.11	17.5	-7.8	4.4		-321.7	96.3	- 0.0		
-20°F AFT	18.33	2.98	6.9	5.9	1.8		- 79.1	-22.4	- 0.9		
25g., 25ms ∩, L											
6.46Hz 140°F	13.05	3.06	1.2	5.0	-4.8	19.8*	- 21.1	0.1	113.6	113.7	*Axial Reaction
7.76 Hz -20°F	15.51	2.52	1.2	6.0	-5.7	23.5*	- 21.1	-0.6	135.1	135.1	*Axial Reaction
15g, 11-18 ms ∩											
13.62Hz 70°F T	11.51	0.61	14.8	-1.1	3.7		-242.4	44.1	- 0.6		
6.81Hz 70°F V	6.01	1.27	7.7	-0.6	1.9		-126.6	23.0	- 0.3		Rebound 1.02g, 0.22 in.
6.81Hz 70°F L	6.01	1.27	1.3	2.3	-2.0	9.1*	- 21.1	2.1	52.3	52.4	*Axial Reaction
15g, 35ms											
6.81 Hz 70°F V	12.56	2.65	16.1	-1.2	4.1		-264.5	48.0	- 0.6		Rebound 2.14g, 0.45 in.
9g, 35ms											
13.62Hz 70°F T	12.68	0.67	16.3	-1.2	4.1		-267.0	48.6	- 0.6		
6g, 35ms											
6.81Hz 70°F L	5.02	1.06	1.3	1.9	-1.7	7.6*	- 21.1	2.4	43.7	43.7	*Axial Reaction

T - Transverse
V - Vertical
L - Longitudinal

DEC - Deceleration
DSP - *Displacement*
MS - Missile Station

TABLE 6

HARPOON CANISTER SHOCK SUMMARY

SHOCK EVENT	DEC (G)	DSP (IN)	REACTION (KIPS) CS 80.52	CS 158.39	CS 158.39*	BENDING MOMENTS (IN-KIPS) CS 80.52	CS 158.39	CS 158.39*	REMARKS
Flat Drop (18")									
6.41Hz 70°F.	14.09	2.98	21.4	6.8		-100.8	-139.0		Rebound 2.40g, 0.51 in.
End Impact (10fps)									
6.46Hz 140°F		2.96							*Guide Pin
7.76Hz -20°F	15.14	2.46	6.2	-4.2	30.4**	- 7.2	353.0	353.0	**Axial Reaction
Rotational Edge Drop									
(18") 6.46Hz FWD		3.16							
140°F AFT		3.05							
7.76Hz FWD	19.22	3.13	19.5	-1.0		-124.7	- 7.5		
-20°F AFT	18.20	2.96	9.3	10.0		- 11.5	-177.2		

DEC - Deceleration
DSP - Displacement
CS - Canister Station

bending moments and axial loads of Tables 5 and 6 indicates that only the -20°F forward edge rotational drop exceeds the design level. The limit equivalent axial load response to this shock is presented in Figure 11. Although the predicted equivalent axial load exceeds the allowable by a small amount from MS 86 to MS 90, damping would lower the predicted response to within the allowable limit as shown by the dashed peak in Figure 11. The canister equivalent axial loads computed from Table 6, were well under the 244,000 pounds allowable having a maximum value of 90.5 kips.

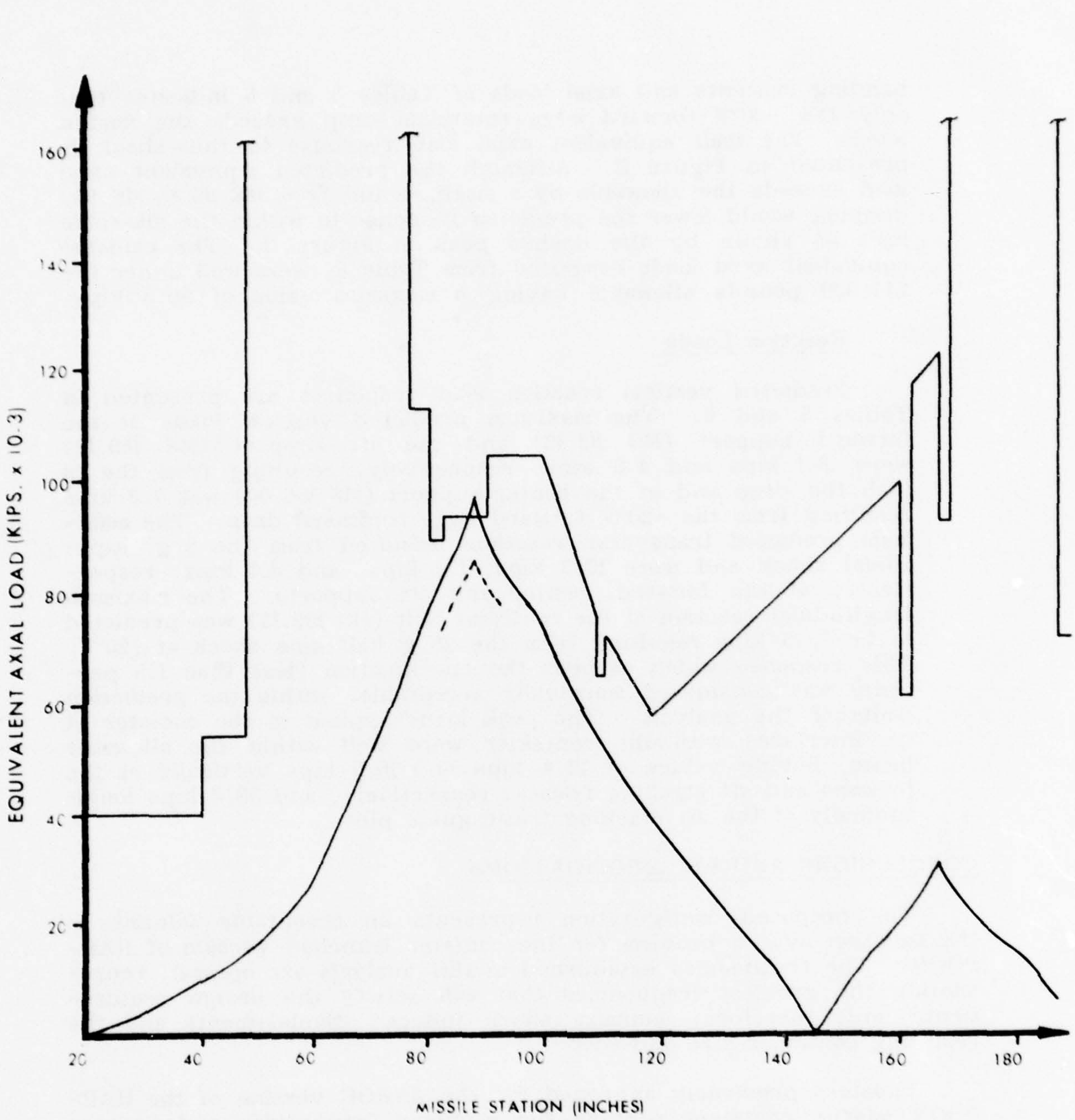
Reaction Loads

Predicted vertical reaction load responses are presented in Tables 5 and 6. The maximum predicted vertical loads at the forward support (MS 88.12) and the aft support (MS 189.12) were 18.1 kips and 4.6 kips, respectively, resulting from the 18 inch flat drop and at the center support (MS 166.00) was 7.8 kips resulting from the -20°F forward edge rotational drop. The maximum predicted transverse reactions resulted from the 9 g trapezoidal shock and were 16.3 kips, 1.2 kips, and 4.1 kips, respectively, at the forward, center and aft supports. The maximum longitudinal reaction at the restraint bolt (MS 192.13) was predicted to be 23.5 kips resulting from the 25 g half sine shock at -20°F. This response which exceeds the specification (less than 1.5 percent) was considered marginally acceptable, within the prediction limits of the analysis. The peak loads applied to the canister at its interfaces with the container were well within the allowable limits, having values of 21.4 kips and 10.0 kips vertically at the forward and aft stacking frames, respectively, and 30.4 kips longitudinally at the aft stacking frame guide pin.

CONCLUSIONS AND RECOMMENDATIONS

The proposed configuration represents an acceptable solution to the isolation system problem for the canister launched version of HARPOON. The frequencies established in this analysis are optimal, representing the greatest frequencies that will satisfy the design requirements and, therefore, minimize shock induced displacements and the resulting container size and cost.

Isolators previously approved for the ASROC version of the HARPOON missile container provide the required frequencies and possess the necessary shape, stiffness and thermal qualities for the proposed application. It is, therefore, recommended that two ASROC version approved isolators be used at each mount location in the configuration presented in this report.



EQUIVALENT AXIAL LOAD COMPARISON OF ALLOWABLE AND PREDICTED RESPONSE TO -20°F FORWARD EDGE ROTATIONAL DROP

——— RESPONSE TO -20°F FORWARD EDGE ROTATIONAL DROP

- - - - ESTIMATED REDUCTION DUE TO DAMPING

FIGURE 11

APPENDIX A

HARPOON MISSILE, CANISTER VERSION

COMPUTER OUTPUT

GLOSSARY OF TERMS USED
IN COMPUTER PRINTOUTS

ADC	DECELERATION- AFT EDGE DROP	G'S
ADS	DISPLACEMENT- AFT EDGE DROP	INCHES
AXL	AXIAL LOAD	POUNDS
DYM	DYNAMIC BENDING MOMENT	INCH-POUNDS
F	FREQUENCY	HERTZ
FDC	DECELERATION- FORWARD EDGE DROP	G'S
FDS	DISPLACEMENT- FORWARD EDGE DROP	INCHES
FR	FRAGILITY	G'S
FREQ	FREQUENCY	HERTZ
IR	ITEM RESPONSE	G'S
IS	ITEM STATION	INCHES
RESP	RESPONSE SHOCK SPECTRUM	G'S
SPAC	HALF-MOUNTSPACING	INCHES
SPEC	SPECIFICATION SHOCK SPECTRUM	G'S

```
**************************************************************************
*                                                                        *
*                                                                        *
*                                                                        *
*   HARPOON MISSILE CANISTER VERSION                                     *
*                                                                        *
*  TRANSVERSE ANALYSIS                                                   *
*                                                                        *
*                                                                        *
*                                                                        *
*  INPUT PARAMETERS                                                      *
*      DAMPING FACTOR                                       0.130        *
*      TRANSVERSE NATURAL FREQUENCY                        14.98 HZ      *
*  RESULTS                                                               *
*      ITEM RESPONSE AT THE NATURAL FREQUENCY               2.78  G      *
*                                                                        *
*  REMARKS                                                               *
*                                                                        *
*                                                                        *
*                                                                        *
**************************************************************************
```

TABLE A-1

TRANSVERSE VIBRATION SUMMARY

FIGURE A-1

TRANSVERSE VIBRATION ANALYSIS
PLOT OF ITEM RESPONSE AND FRAGILITY VS FREQUENCY
ITEM RESPONSE (IR) = *
FRAGILITY (FR) = +

```
    F   FR    IR 0.0                                               5.0
   HZ    G     G  +-------------------------------------------------+
  5.0  5.00  1.46 I             *                                   +
  6.0  5.00  1.49 I              *                                  +
  7.0  5.00  1.59 I               *                                 +
  8.0  5.00  1.73 I                *                                +
  9.0  5.00  1.38 I             *                                   +
 10.0  5.00  1.14 I          *                                      +
 11.0  5.00  1.33 I            *                                    +
 12.0  5.00  1.60 I               *                                 +
 13.0  5.00  2.05 I                   *                             +
 14.0  5.00  2.63 I                         *                       +
 15.0  5.00  2.78 I                          *                      +
 16.0  5.00  2.40 I                       *                         +
 17.0  5.00  1.82 I                 *                               +
 18.0  5.00  1.39 I             *                                   +
 19.0  5.00  1.10 I          *                                      +
 20.0  3.00  0.99 I         *                   +
 21.0  3.00  0.91 I        *                    +
 22.0  3.00  0.83 I       *                     +
 23.0  3.00  0.80 I       *                     +
 24.0  3.00  0.77 I       *                     +
 25.0  2.00  0.74 I      *            +
 26.0  2.00  0.37 I   *               +
 27.0  2.00  0.36 I   *               +
 28.0  2.00  0.35 I  *                +
 29.0  2.00  0.34 I  *                +
 30.0  2.00  0.33 I  *                +
 31.0  2.00  0.32 I  *                +
 32.0  2.00  0.33 I  *                +
 33.0  2.00  0.33 I  *                +
 34.0  2.00  0.21 I *                 +
 35.0  2.00  0.20 I *                 +
 36.0  2.00  0.19 I *                 +
 37.0  2.00  0.18 I *                 +
 38.0  2.00  0.18 I *                 +
 39.0  2.00  0.17 I *                 +
 40.0  2.00  0.16 I *                 +
 50.0  2.00  0.13 I*                  +
 60.0  2.00  0.13 I*                  +
 70.0  2.00  0.12 I*                  +
 80.0  2.00  0.11 I*                  +
 90.0  2.00  0.11 I*                  +
100.0  0.25  0.10 I*+
150.0  0.25  0.10 I*+
200.0  0.25  0.08 I*+
250.0  2.00  0.07 I*                  +
300.0  2.00  0.05 I*                  +
350.0  2.00  0.06 I*                  +
400.0  2.00  0.05 *                   +
500.0  2.00  0.02 *                   +
```

```
******************************************************************
*                                                                *
*                                                                *
*                                                                *
*   HARPOON MISSILE CANISTER VERSION                             *
*                                                                *
*  VERTICAL ANALYSIS                                             *
*                                                                *
*                                                                *
*                                                                *
*  INPUT PARAMETERS                                              *
*      DAMPING FACTOR                                  0.130     *
*      VERTICAL NATURAL FREQUENCY                      7.49 HZ   *
*  RESULTS                                                       *
*      ITEM RESPONSE AT THE NATURAL FREQUENCY          4.97  G   *
*                                                                *
*  REMARKS                                                       *
*                                                                *
*                                                                *
*                                                                *
******************************************************************
```

TABLE A-2

VERTICAL VIBRATION SUMMARY

FIGURE A-2

VERTICAL VIBRATION ANALYSIS
PLOT OF ITEM RESPONSE AND FRAGILITY VS FREQUENCY
ITEM RESPONSE (IR) = *
FRAGILITY (FR) = +

```
  F     FR    IR 0.0                                              5.0
  HZ    G     G   +-------------------------------------------------+
  5.0  5.00  3.06 I                              *                  +
  6.0  5.00  3.08 I                              *                  +
  7.0  5.00  4.70 I                                              *  +
  8.0  5.00  4.17 I                                         *       +
  9.0  5.00  2.41 I                       *                         +
 10.0  5.00  1.55 I              *                                  +
 11.0  5.00  1.10 I          *                                      +
 12.0  5.00  0.84 I       *                                         +
 13.0  5.00  0.48 I    *                                            +
 14.0  5.00  0.31 I  *                                              +
 15.0  5.00  0.26 I  *                                              +
 16.0  5.00  0.23 I *                                               +
 17.0  5.00  0.20 I *                                               +
 18.0  5.00  0.18 I *                                               +
 19.0  5.00  0.16 I *                                               +
 20.0  3.00  0.16 I *                           +
 21.0  3.00  0.16 I *                           +
 22.0  3.00  0.16 I *                           +
 23.0  3.00  0.16 I *                           +
 24.0  3.00  0.16 I *                           +
 25.0  2.00  0.16 I *                 +
 26.0  2.00  0.09 I*                  +
 27.0  2.00  0.09 I*                  +
 28.0  2.00  0.09 I*                  +
 29.0  2.00  0.09 I*                  +
 30.0  2.00  0.09 I*                  +
 31.0  2.00  0.09 I*                  +
 32.0  2.00  0.09 I*                  +
 33.0  2.00  0.09 I*                  +
 34.0  2.00  0.06 I*                  +
 35.0  2.00  0.06 I*                  +
 36.0  2.00  0.06 I*                  +
 37.0  2.00  0.05 I*                  +
 38.0  2.00  0.05 I*                  +
 39.0  2.00  0.05 I*                  +
 40.0  2.00  0.05 *                   +
 50.0  2.00  0.05 *                   +
 60.0  2.00  0.05 I*                  +
 70.0  2.00  0.05 *                   +
 80.0  2.00  0.05 *                   +
 90.0  2.00  0.05 *                   +
100.0  0.25  0.05 * +
150.0  0.25  0.05 * +
200.0  0.25  0.04 * +
250.0  2.00  0.03 *                   +
300.0  2.00  0.03 *                   +
350.0  2.00  0.03 *                   +
400.0  2.00  0.02 *                   +
500.0  2.00  0.01 *                   +
```

```
*****************************************************************
*                                                               *
*                                                               *
*                                                               *
*   HARPOON MISSILE CANISTER VERSION                            *
*                                                               *
*  LONGITUDINAL ANALYSIS                                        *
*                                                               *
*                                                               *
*                                                               *
*  INPUT PARAMETERS                                             *
*      DAMPING FACTOR                               0.130       *
*      LONGITUDINAL NATURAL FREQUENCY               7.49 HZ     *
*  RESULTS                                                      *
*      ITEM RESPONSE AT THE NATURAL FREQUENCY       1.03  G     *
*                                                               *
*  REMARKS                                                      *
*                                                               *
*                                                               *
*                                                               *
*****************************************************************
```

TABLE A-3

LONGITUDINAL VIBRATION SUMMARY

FIGURE A-3

LONGITUDINAL VIBRATION ANALYSIS
PLOT OF ITEM RESPONSE AND FRAGILITY VS FREQUENCY
ITEM RESPONSE (IR) = *
FRAGILITY (FR) = +

F HZ	FR G	IR G
5.0	2.00	0.19
6.0	2.00	0.39
7.0	2.00	0.86
8.0	2.00	1.00
9.0	2.00	0.64
10.0	2.00	0.45
11.0	2.00	0.33
12.0	2.00	0.30
13.0	2.00	0.29
14.0	2.00	0.26
15.0	2.00	0.26
16.0	2.00	0.16
17.0	2.00	0.16
18.0	2.00	0.16
19.0	2.00	0.16
20.0	2.00	0.16
21.0	2.00	0.16
22.0	2.00	0.16
23.0	2.00	0.15
24.0	2.00	0.16
25.0	2.00	0.16
26.0	2.00	0.09
27.0	2.00	0.09
28.0	2.00	0.09
29.0	2.00	0.09
30.0	2.00	0.09
31.0	2.00	0.09
32.0	2.00	0.09
33.0	2.00	0.09
34.0	2.00	0.05
35.0	2.00	0.05
36.0	2.00	0.05
37.0	2.00	0.05
38.0	2.00	0.05
39.0	2.00	0.05
40.0	2.00	0.05
50.0	2.00	0.05
60.0	2.00	0.05
70.0	2.00	0.05
80.0	2.00	0.05
90.0	2.00	0.05
100.0	0.25	0.05
150.0	0.25	0.05
200.0	0.25	0.04
250.0	2.00	0.03
300.0	2.00	0.03
350.0	2.00	0.03
400.0	2.00	0.02
500.0	2.00	0.01

```
***********************************************************************
*                                                                     *
*                                                                     *
*                                                                     *
*  FLAT DROP- HARPOON MISSILE CANISTER VERSION                        *
*                                                                     *
*                                                                     *
* INPUT PARAMETERS                                                    *
* ----------------                                                    *
*                                                                     *
*                                                                     *
*                                                                     *
*                                                                     *
*    SUPPORT LOCATIONS(IS)          FWD              88.12            *
*                                   CTR             166.00            *
*                                   AFT             189.12            *
*    VERTICAL SHOCK FREQ                              6.81 HZ         *
*    DROP HEIGHT                                     18.00 INS        *
*    WEIGHT OF THE CONTAINER SHELL                  500.00 LBS        *
*    WEIGHT OF CRADLE                               917.50 LBS        *
*                                                                     *
*                                                                     *
* RESULTS                                                             *
* -------                                                             *
*                                                                     *
*                                                                     *
*  PRIMARY-                                                           *
*    DISPLACEMENT                                     2.98 INS        *
*    DECELERATION                                    14.09 G          *
*  REBOUND-                                                           *
*    DISPLACEMENT                                     0.51 INS        *
*    DECELERATION                                     2.40 G          *
*    DYNAMIC SUPPORT REACTIONS      FWD           18109.20 LBS        *
*                                   CTR           -1313.42 LBS        *
*                                   AFT            4556.98 LBS        *
*    DYN BENDING MOM AT SUPPORTS-   FWD         -296769.81 IN-LBS     *
*                                   CTR           53985.87 IN-LBS     *
*                                   AFT            -675.01 IN-LBS     *
* REMARKS                                                             *
*                                                                     *
*                                                                     *
*                                                                     *
***********************************************************************
```

TABLE A-4

FLAT DROP SUMMARY

FIGURE A-4

DYNAMIC BENDING MOMENTS
18 INCH FLAT DROP

```
IS      MOM 0            75000         150000         225000         300000
IN   IN-LBS+--------------+--------------+--------------+--------------+
  0       0.+
  5       0.+
 10       0.+
 15       0.+
 20    -148.+
 25    -581.+
 30   -6399.I+
 35  -12381.I +
 40  -19837.I   +
 45  -29887.I     +
 49  -42712.I        +
 54  -58975.I           +
 59  -81387.I               +
 64 -110185.I                     +
 69 -141523.I                           +
 74 -175599.I                                  +
 79 -215282.I                                          +
 84 -259550.I                                                   +
 88 -296769.I                                                          +
 94 -250257.I                                                 +
 99 -213471.I                                          +
104 -179522.I                                   +
109 -149364.I                             +
114 -120666.I                       +
119  -95181.I                  +
124  -70157.I             +
129  -47334.I        +
134  -25317.I    +
139   -6420.I+
144    8994.I +
148   22009.I   +
153   33553.I      +
158   42753.I        +
163   51241.I          +
166   53986.I          +
173   46490.I         +
178   39232.I       +
183   21901.I   +
189    -675.I+
193      -0.+
```

```
 END IMPACT- HARPOON MISSILE CANISTER VERSION


INPUT PARAMETERS
----------------


    SUPPORT LOCATIONS(IS)              FWD                         88.12
                                       CTR                        166.00
                                       AFT                        189.12
    LONGITUDINAL SHOCK FREQUENCY-HIGH TEMPERATURE                   6.46 HZ
                                      LOW TEMPERATURE               7.76 HZ
    IMPACT VELOCITY                                                10.00 FPS
    NUMBER OF LONGITUDINAL BEARING RESTAINTS                          1
    LOCATION OF LONG BEARING RESTRAINTS(IS)                       192.13
    ECCENTRICITIES                                                  5.75 INS


RESULTS
-------


                AT LOW TEMPERATURE

    DECELERATION                                                   15.14 G
    DYNAMIC SUPPORT REACTIONS          FWD                       1229.64 LBS
                                       CTR                       5853.83 LBS
                                       AFT                      -5568.29 LBS
    DYN BENDING MOM AT SUPPORTS-       FWD                     -21058.62 IN-LBS
                                       CTR                       -482.24 IN-LBS
                                       AFT                     131854.01 IN-LBS

    DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS
    1ST BEARING RESTRAINT             131901.90                    -0.00 IN-LBS


                AT HIGH TEMPERATURE

    DISPLACEMENT                                                    2.96 INS

REMARKS
          HIGH TEMP = 140 F    LOW TEMP = -20 F
```

TABLE A-5

END IMPACT SUMMARY

FIGURE A-5

DYNAMIC BENDING MOMENTS
10 FPS END IMPACT

```
 IS      MOM  0            33000        66000        99000        132000
 IN  IN-LBS+-------------+-------------+-------------+-------------+
  0       0.+
  5       0.+
 10       0.+
 15       0.+
 20     -11.+
 25     -41.+
 30    -454.+
 35    -879.+
 40   -1408.I+
 45   -2121.I+
 49   -3031.I+
 54   -4185.I +
 59   -5775.I +
 64   -7319.I  +
 69  -10042.I   +
 74  -12460.I    +
 79  -15276.I     +
 84  -18417.I       +
 88  -21058.I        +
 94  -18085.I       +
 99  -15749.I      +
104  -13614.I     +
109  -11748.I    +
114   -9986.I   +
119   -8451.I   +
124   -6950.I  +
129   -5604.I +
134   -4316.I +
139   -3249.I+
144   -2429.I+
148   -1780.I+
153   -1235.I+
158    -856.+
163    -528.+
166    -482.+
173   41436.I                 +
178   70077.I                            +
183   98003.I                                        +
189  131854.I                                                      +
192  131901.I                                                      +
```

```
***************************************************************
*                                                             *
*                                                             *
*                                                             *
*  END IMPACT-AXIAL LOADS                                     *
*                                                             *
*                                                             *
*          HARPOON MISSILE CANISTER VERSION                   *
*                                                             *
*    DYNAMIC AXIAL LOADS AT LONGITUDINAL RESTRAINTS           *
*     1ST BEARING RESTRAINT          22939.46          LBS    *
*                                                             *
* REMARKS                                                     *
*                                                             *
*                                                             *
*                                                             *
*                                                             *
***************************************************************
```

TABLE A-6

AXIAL LOAD SUMMARY
10 FPS END IMPACT

FIGURE A-6

DYNAMIC AXIAL LOADS
10 FPS END IMPACT

IS IN	AXL LBS
0	0.
5	9.
10	17.
15	26.
20	256.
25	675.
30	1145.
35	1521.
40	1921.
45	2457.
49	3148.
54	4246.
59	5456.
64	6357.
69	7235.
74	8087.
79	9006.
84	9910.
89	10596.
94	11217.
99	11836.
104	12479.
109	13093.
114	13565.
119	13976.
124	14263.
129	14577.
134	15018.
139	15710.
144	16359.
148	16801.
153	17187.
158	17563.
163	18172.
168	18840.
173	19669.
178	20706.
183	21787.
188	22346.
192	22939.

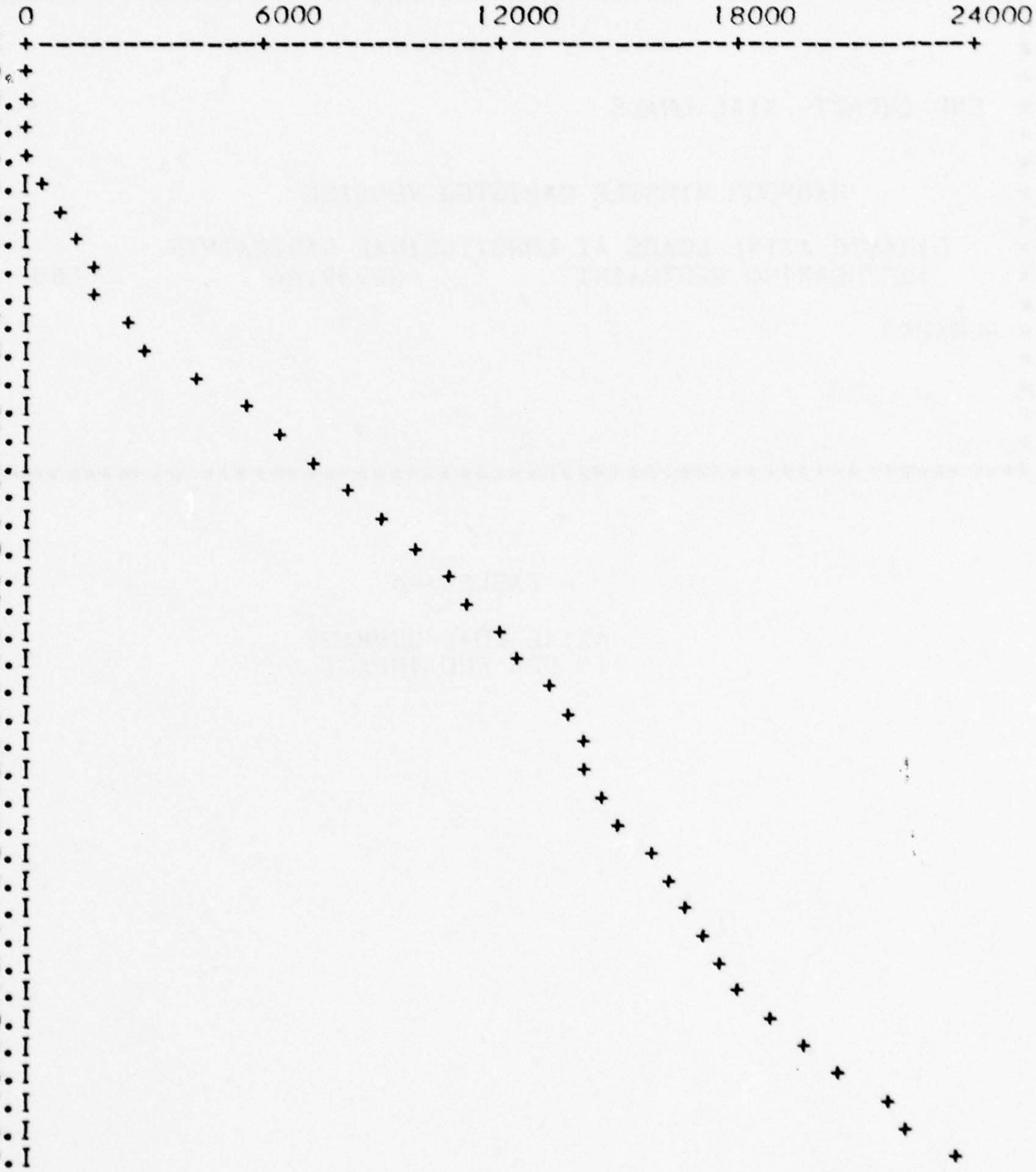


FIGURE A-7

PLOT OF DECELERATION VS HALF-MOUNTSPACING
FORWARD AND AFT DROPS AT -20°F
FORWARD DROP = +
AFT DROP = *

SPAC IN	FDC G	ADC G
10	10.66	11.07
13	11.05	11.40
15	11.44	11.74
18	11.82	12.07
20	12.21	12.40
23	12.60	12.74
25	12.98	13.07
28	13.37	13.40
30	13.76	13.74
33	14.15	14.07
35	14.53	14.40
38	14.92	14.74
40	15.31	15.07
43	15.69	15.40
45	16.08	15.74
48	16.47	16.07
50	16.85	16.40
53	17.24	16.74
55	17.63	17.07
58	18.01	17.41
61	18.40	17.74
63	18.79	18.07
66	19.17	18.41
68	19.56	18.74
71	19.95	19.07
73	20.33	19.41
76	20.72	19.74
78	21.11	20.07
81	21.50	20.41
83	21.88	20.74
86	22.27	21.07
88	22.66	21.41
91	23.04	21.74
93	23.43	22.07
96	23.82	22.41
98	24.20	22.74
101	24.59	23.07
103	24.98	23.41
106	25.36	23.74
109	25.75	24.08

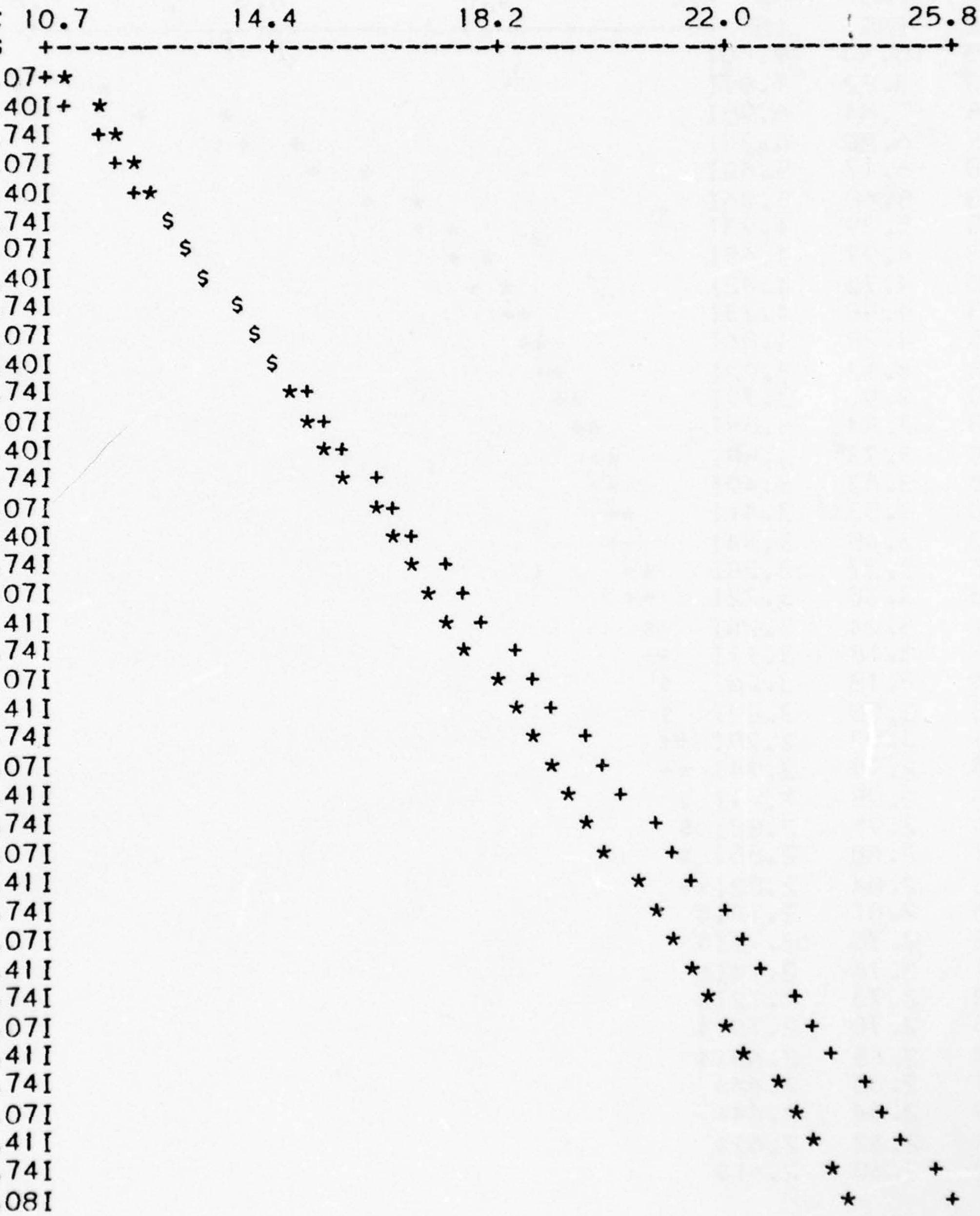


FIGURE A-8

PLOT OF DISPLACEMENT VS HALF-MOUNTSPACING
FORWARD AND AFT DROPS AT 140°F
FORWARD DROP = +
AFT DROP = *

```
SPAC   FDS      ADS 2.6         4.6         6.6         8.6        10.6
  IN   INS      INS +-----------+-----------+-----------+-----------+
  10  10.50     9.50I                                         *     +
  13   8.82     7.97I                                *    +
  15   7.64     6.95I                          *    +
  18   6.80     6.23I                      *  +
  20   6.17     5.69I                  *  +
  23   5.68     5.26I                * +
  25   5.29     4.93I              * +
  28   4.97     4.65I            * +
  30   4.70     4.42I           * +
  33   4.48     4.23I           *+
  35   4.28     4.06I          *+
  38   4.12     3.92I         *+
  40   3.97     3.79I        *+
  43   3.84     3.68I       *+
  45   3.73     3.58I      *+
  48   3.63     3.49I      *+
  50   3.53     3.41I     *+
  53   3.45     3.34I     *+
  55   3.37     3.28I    *+
  58   3.30     3.22I    *+
  61   3.24     3.16I    $
  63   3.18     3.11I   *+
  66   3.13     3.06I   $
  68   3.08     3.02I   $
  71   3.03     2.98I  *+
  73   2.99     2.94I  *+
  76   2.95     2.91I  $
  78   2.91     2.88I  $
  81   2.88     2.85I  $
  83   2.84     2.82I*+
  86   2.81     2.79I$
  88   2.78     2.77I$
  91   2.76     2.74I$
  93   2.73     2.72I$
  96   2.70     2.70I$
  98   2.68     2.68I$
 101   2.66     2.66$
 103   2.64     2.64$
 106   2.62     2.62$
 109   2.60     2.61$
```

```
 ROTATIONAL EDGEWISE DROP
        HARPOON MISSILE CANISTER VERSION

INPUT PARAMETERS
----------------
   HALF MOUNT SPACING                                65.00 INS
   SUPPORT LOCATIONS(IS)            FWD              88.12
                                    CTR             166.00
                                    AFT             189.12
   OVERALL CONTAINER LENGTH                         217.00 INS
   ITEM PITCH MOMENT OF INERTIA                   10240.80 IN-LB-SECSQ
   DISTANCE ITEM C.G. TO CONT BASE                   25.19 INS
   DISTANCE ITEM C.G. TO CONT FORWARD END           112.25 INS
   DROP HEIGHT                                       18.00 INS
   VERTICAL FREQUENCY-LOW TEMPERATURE                 7.76 HZ
   VERTICAL FREQUENCY-HIGH TEMPERATURE                6.46 HZ
   LOCATION FOR DEC CALCULATIONS-FORWARD              9.63 (IS)
   LOCATION FOR DEC CALCULATIONS-AFT                191.83 (IS)
   LOCATION FOR DSPL CALCULATIONS-FORWARD             9.63 (IS)
   LOCATION FOR DSPL CALCULATIONS-AFT               191.83 (IS)
   CRADLE WEIGHT                                    917.50 LBS
   CRADLE C.G. LOCATION                             108.70 (IS)
   CRADLE PITCH MOMENT OF INERTIA                  8330.40 IN-LB-SECSQ

RESULTS
-------
   TOTAL WEIGHT OF ITEM AND CRADLE                 2432.68 LBS
   TOTAL PITCH MOMENT OF INERTIA                  18592.75 IN-LB-SECSQ
   TOTAL C.G. IS LOCATED AT                         106.32 (IS)

              AT LOW TEMPERATURE (-20°F)

 FORWARD EDGE DROP
   MAXIMUM DECELERATION AT(IS)      9.63                       19.09 G
   DYNAMIC SUPPORT REACTIONS        FWD                     17495.64 LBS
                                    CTR                     -7801.59 LBS
                                    AFT                      4366.75 LBS
   DYN BENDING MOM AT SUPPORTS-     FWD                   -321743.39 IN-LBS
                                    CTR                     96276.13 IN-LBS
                                    AFT                       -24.71 IN-LBS
 AFT EDGE DROP
   MAXIMUM DECELERATION AT(IS)    191.83                       18.33 G
   DYNAMIC SUPPORT REACTIONS        FWD                      6910.65 LBS
                                    CTR                      5867.20 LBS
                                    AFT                      1773.92 LBS
   DYN BENDING MOM AT SUPPORTS-     FWD                    -79102.40 IN-LBS
                                    CTR                    -22408.55 IN-LBS
                                    AFT                      -869.24 IN-LBS

              AT HIGH TEMPERATURE (140°F)

   FWD EDGE DROP DISPLACEMENT AT(IS)   9.63                     3.14 INS
   AFT EDGE DROP DISPLACEMENT AT(IS) 191.83                     3.07 INS
```

TABLE A-7

ROTATIONAL EDGEWISE DROP SUMMARY

FIGURE A-9

PLOT OF DECELERATION AT ITEM STATIONS
FOR HALF-MOUNTSPACING 65 INCHES
FORWARD AND AFT DROPS AT -20°F
FORWARD DROP = +
AFT DROP = *

IS IN	FDC G	ADC G
0	20.08	-0.92
5	19.57	-0.43
10	19.06	0.07
15	18.55	0.57
20	18.04	1.06
25	17.53	1.56
30	17.02	2.06
35	16.51	2.55
40	16.00	3.05
45	15.49	3.55
49	14.98	4.04
54	14.47	4.54
59	13.96	5.04
64	13.46	5.53
69	12.95	6.03
74	12.44	6.53
79	11.93	7.02
84	11.42	7.52
89	10.91	8.02
94	10.40	8.51
99	9.89	9.01
104	9.38	9.51
109	8.87	10.00
114	8.36	10.50
119	7.85	11.00
124	7.34	11.49
129	6.83	11.99
134	6.32	12.49
139	5.81	12.98
144	5.30	13.48
148	4.79	13.98
153	4.28	14.47
158	3.77	14.97
163	3.26	15.47
168	2.75	15.97
173	2.25	16.46
178	1.74	16.96
183	1.23	17.46
188	0.72	17.95
193	0.21	18.45

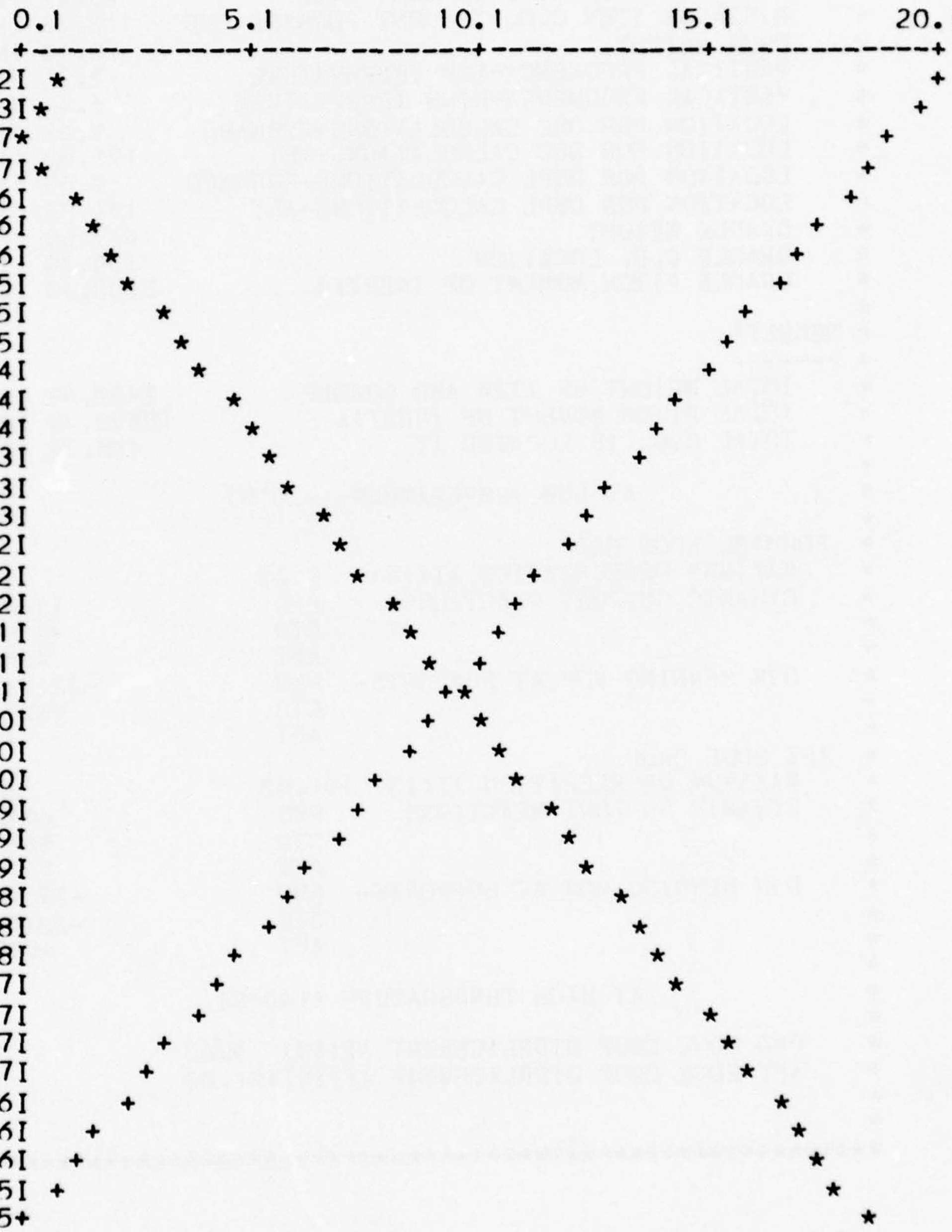


FIGURE A-10

PLOT OF DISPLACEMENT AT ITEM STATIONS
FOR HALF-MOUNTSPACING 65 INCHES
FORWARD AND AFT DROPS AT 140°F
FORWARD DROP = +
AFT DROP = *

IS IN	FDS INS	ADS INS
0	3.28	0.45
5	3.21	0.52
10	3.14	0.59
15	3.07	0.65
20	3.00	0.72
25	2.93	0.79
30	2.86	0.86
35	2.79	0.93
40	2.72	0.99
45	2.65	1.06
49	2.58	1.13
54	2.51	1.20
59	2.44	1.26
64	2.37	1.33
69	2.30	1.40
74	2.23	1.47
79	2.17	1.53
84	2.10	1.60
89	2.03	1.67
94	1.96	1.74
99	1.89	1.80
104	1.82	1.87
109	1.75	1.94
114	1.68	2.01
119	1.61	2.08
124	1.54	2.14
129	1.47	2.21
134	1.40	2.28
139	1.33	2.35
144	1.26	2.41
148	1.19	2.48
153	1.12	2.55
158	1.05	2.62
163	0.99	2.68
168	0.92	2.75
173	0.85	2.82
178	0.78	2.89
183	0.71	2.95
188	0.64	3.02
193	0.57	3.09

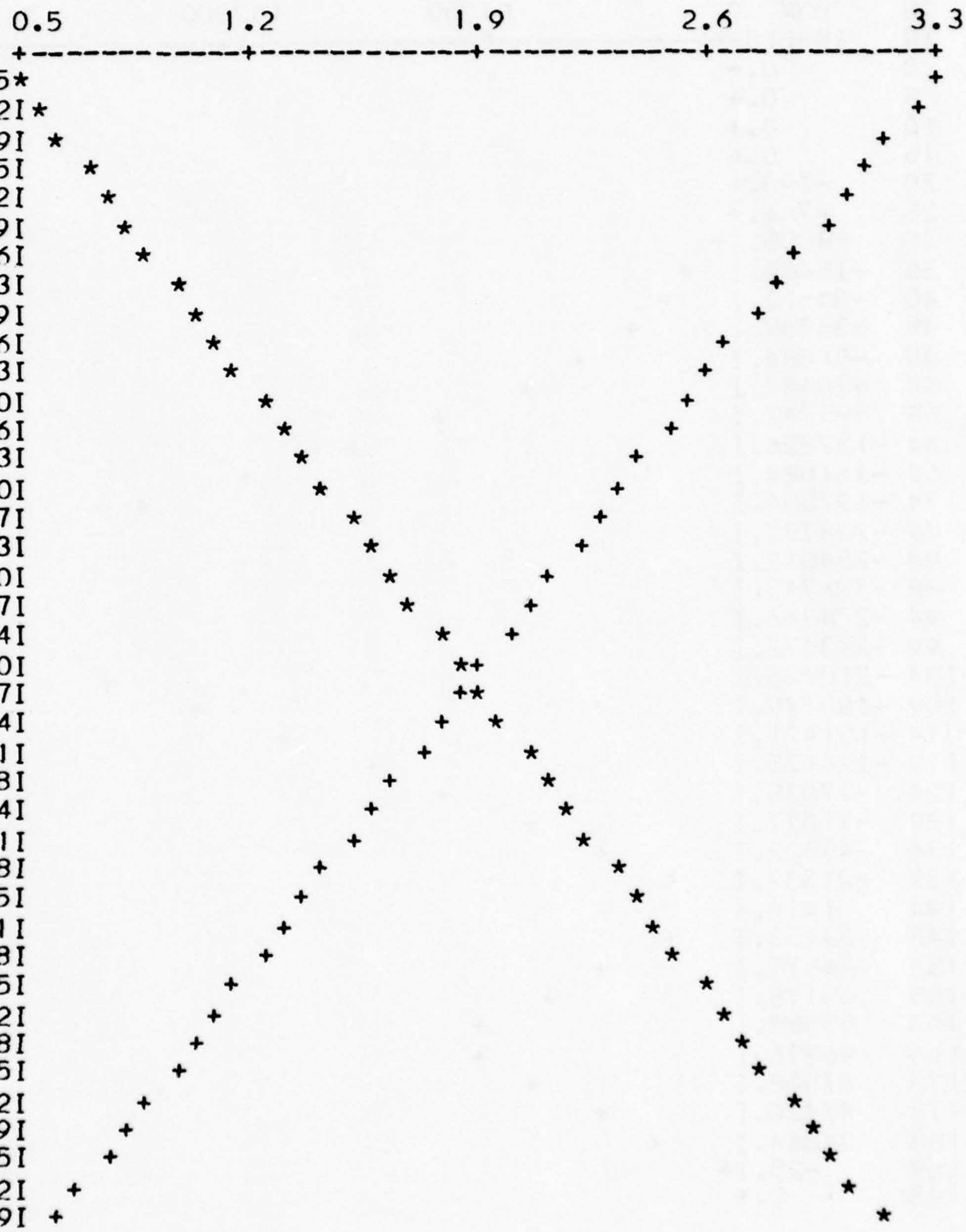


FIGURE A-11

DYNAMIC BENDING MOMENTS
18 INCH FORWARD EDGE ROTATIONAL DROP

Scale: 0 — 81000 — 162000 — 243000 — 324000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	0.
20	-193.
25	-746.
30	-8005.
35	-15460.
40	-24612.
45	-36739.
49	-51886.
54	-70687.
59	-95747.
64	-127226.
69	-161084.
74	-197504.
79	-238787.
84	-284019.
88	-321743.
94	-278366.
99	-243672.
104	-210926.
109	-180749.
114	-151471.
119	-124125.
124	-97035.
129	-71077.
134	-45522.
139	-21337.
144	1418.
148	23233.
153	44577.
158	65178.
163	85589.
166	96276.
173	67508.
178	47420.
183	26064.
189	-25.
193	0.

FIGURE A-12

DYNAMIC BENDING MOMENTS
18 INCH AFT EDGE ROTATIONAL DROP

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	0.
20	-8.
25	-41.
30	-665.
35	-1314.
40	-2260.
45	-3738.
49	-5945.
54	-9140.
59	-14372.
64	-21796.
69	-30264.
74	-39857.
79	-52129.
84	-66619.
88	-79102.
94	-59833.
99	-44970.
104	-31963.
109	-21469.
114	-12031.
119	-4962.
124	1747.
129	6646.
134	10873.
139	12304.
144	10521.
148	6478.
153	949.
158	-6959.
163	-15622.
166	-22408.
173	-4284.
178	5694.
183	3576.
189	-869.
193	0.

```
**************************************************************************
*                                                                        *
*                                                                        *
*                                                                        *
*             HARPOON MISSILE CANISTER VERSION                           *
*                                                                        *
*                                                                        *
* INPUT PARAMETERS                                                       *
* ----------------                                                       *
*                                                                        *
*                                                                        *
*    SUPPORT LOCATIONS(IS)            FWD                 88.12          *
*                                     CTR                166.00          *
*                                     AFT                189.12          *
*    LONGITUDINAL SHOCK FREQUENCY-HIGH TEMPERATURE          6.46 HZ      *
*                                LOW TEMPERATURE           6.46 HZ      *
*    IMPACT VELOCITY                                      10.35 FPS     *
*    NUMBER OF LONGITUDINAL BEARING RESTAINTS                1          *
*    LOCATION OF LONG BEARING RESTRAINTS(IS)             192.13          *
*    ECCENTRICITIES                                        5.75 INS     *
*                                                                        *
*                                                                        *
* RESULTS                                                                *
* -------                                                                *
*                                                                        *
*                                                                        *
*             AT LOW TEMPERATURE                                         *
*                                                                        *
*    DECELERATION                                         13.05 G       *
*    DYNAMIC SUPPORT REACTIONS        FWD               1237.28 LBS     *
*                                     CTR               5032.96 LBS     *
*                                     AFT              -4755.06 LBS     *
*    DYN BENDING MOM AT SUPPORTS-     FWD             -21058.62 IN-LBS  *
*                                     CTR                113.09 IN-LBS  *
*                                     AFT             113647.42 IN-LBS  *
*                                                                        *
*    DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS                  *
*    1ST BEARING RESTRAINT           113695.32            -0.00 IN-LBS  *
*                                                                        *
*                                                                        *
*             AT HIGH TEMPERATURE                                        *
*                                                                        *
*    DISPLACEMENT                                          3.06 INS     *
*                                                                        *
* REMARKS                                                                *
*         IMPACT VELOCITY EQUIVALENT NOT ACTUAL SEE TEXT                 *
*         HIGH TEMP = LOW TEMP = 140°F                                   *
*                                                                        *
*                                                                        *
*                                                                        *
**************************************************************************
```

TABLE A-8

RESPONSE TO LONGITUDINAL 25G,25MS HALF SINE SHOCK AT 140°F
SUMMARY

FIGURE A-13

DYNAMIC BENDING MOMENTS
RESPONSE TO LONGITUDINAL 25G,25MS HALF SINE SHOCK AT 140°F

```
 IS     MOM  0              29000          58000          87000          116000
 IN    IN-LBS+--------------+--------------+--------------+--------------+
  0        0.+
  5        0.+
 10        0.+
 15        0.+
 20      -11.+
 25      -41.+
 30     -454.+
 35     -879.+
 40    -1408.I+
 45    -2121.I+
 49    -3031.I+
 54    -4185.I +
 59    -5775.I  +
 64    -7819.I   +
 69   -10042.I    +
 74   -12460.I     +
 79   -15276.I      +
 84   -18417.I        +
 88   -21059.I          +
 94   -18040.I        +
 99   -15666.I       +
104   -13493.I      +
109   -11589.I     +
114    -9789.I    +
119    -8217.I   +
124    -6678.I  +
129    -5294.I  +
134    -3968.I +
139    -2864.I+
144    -2006.I+
148    -1319.I+
153     -736.+
158     -319.+
163       47.+
166      113.+
173    36172.I                 +
178    60789.I                              +
183    84690.I                                           +
189   113647.I                                                            +
192   113695.I                                                            +
```

```
****************************************************************
*                                                              *
*                                                              *
*                                                              *
*            AXIAL LOADS                                       *
*                                                              *
*                                                              *
*         HARPOON MISSILE CANISTER VERSION                     *
*                                                              *
*    DYNAMIC AXIAL LOADS AT LONGITUDINAL RESTRAINTS            *
*     1ST BEARING RESTRAINT            19773.10          LBS   *
*                                                              *
* REMARKS                                                      *
*                                                              *
*                                                              *
*                                                              *
*                                                              *
****************************************************************
```

TABLE A-9

AXIAL LOAD SUMMARY
RESPONSE TO LONGITUDINAL 25G,25MS HALF SINE SHOCK AT 140°F

FIGURE A-14

DYNAMIC AXIAL LOADS
RESPONSE TO LONGITUDINAL 25G,25MS HALF SINE SHOCK AT 140°F

IS IN	AXL LBS
0	0.
5	7.
10	15.
15	22.
20	221.
25	582.
30	987.
35	1311.
40	1656.
45	2118.
49	2713.
54	3660.
59	4703.
64	5480.
69	6236.
74	6971.
79	7763.
84	8542.
89	9134.
94	9668.
99	10202.
104	10756.
109	11286.
114	11692.
119	12047.
124	12295.
129	12565.
134	12945.
139	13542.
144	14101.
148	14482.
153	14815.
158	15138.
163	15664.
168	16240.
173	16954.
178	17848.
183	18779.
188	19262.
192	19773.

Axis: 0 5000 10000 15000 20000

HARPOON MISSILE CANISTER VERSION

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	88.12
	CTR	166.00
	AFT	189.12
LONGITUDINAL SHOCK FREQUENCY-HIGH TEMPERATURE		7.76 HZ
	LOW TEMPERATURE	7.76 HZ
IMPACT VELOCITY		10.24 FPS
NUMBER OF LONGITUDINAL BEARING RESTAINTS		1
LOCATION OF LONG BEARING RESTRAINTS(IS)		192.13
ECCENTRICITIES		5.75 INS

RESULTS

AT LOW TEMPERATURE

DECELERATION		15.51 G
DYNAMIC SUPPORT REACTIONS	FWD	1228.28 LBS
	CTR	5999.26 LBS
	AFT	-5712.37 LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-21058.62 IN-LBS
	CTR	-587.72 IN-LBS
	AFT	135079.64 IN-LBS

DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS

1ST BEARING RESTRAINT	135127.54	-0.00 IN-LBS

AT HIGH TEMPERATURE

DISPLACEMENT	2.52 INS

REMARKS

IMPACT VELOCITY EQUIVALENT NOT ACTUAL SEE TEXT

HIGH TEMP = LOW TEMP = -20°F

TABLE A-10

RESPONSE TO LONGITUDINAL 25G,25MS HALF SINE SHOCK AT -20°F
SUMMARY

FIGURE A-15

DYNAMIC BENDING MOMENTS
RESPONSE TO LONGITUDINAL 25G, 25MS HALF SINE SHOCK AT -20°F

IS IN	MOM IN-LBS
0	0.
5	0.
10	0.
15	0.
20	-11.
25	-41.
30	-454.
35	-879.
40	-1408.
45	-2121.
49	-3031.
54	-4185.
59	-5775.
64	-7819.
69	-10042.
74	-12460.
79	-15276.
84	-18417.
88	-21059.
94	-18093.
99	-15764.
104	-13635.
109	-11776.
114	-10020.
119	-8493.
124	-6998.
129	-5659.
134	-4378.
139	-3318.
144	-2505.
148	-1862.
153	-1323.
158	-951.
163	-630.
166	-588.
173	42369.
178	71723.
183	100362.
189	135080.
192	135128.

Plot scale: 0, 34000, 68000, 102000, 136000

```
****************************************************************
*                                                              *
*                                                              *
*                                                              *
*           AXIAL LOADS                                        *
*                                                              *
*                                                              *
*        HARPOON MISSILE CANISTER VERSION                      *
*                                                              *
*   DYNAMIC AXIAL LOADS AT LONGITUDINAL RESTRAINTS             *
*    1ST BEARING RESTRAINT          23500.44        LBS        *
*                                                              *
* REMARKS                                                      *
*                                                              *
*                                                              *
*                                                              *
*                                                              *
****************************************************************
```

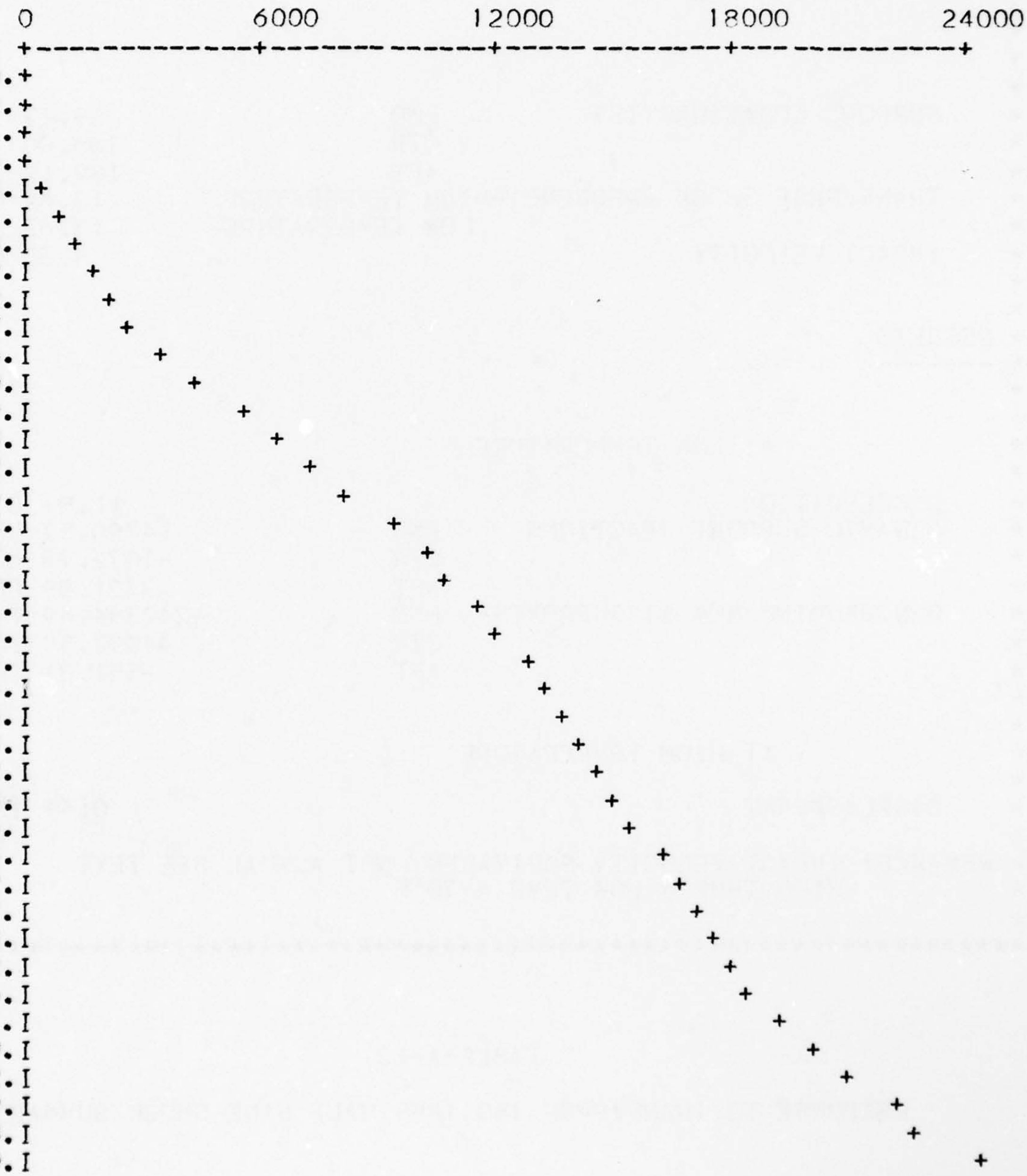
TABLE A-11

AXIAL LOAD SUMMARY
RESPONSE TO LONGITUDINAL 25G,25MS HALF SINE SHOCK AT -20°F

FIGURE A-16

DYNAMIC AXIAL LOADS
RESPONSE TO LONGITUDINAL 25G,25MS HALF SINE SHOCK AT -20°F

IS IN	AXL LBS
0	0.
5	9.
10	18.
15	26.
20	263.
25	691.
30	1173.
35	1559.
40	1968.
45	2517.
49	3224.
54	4350.
59	5589.
64	6513.
69	7412.
74	8285.
79	9227.
84	10152.
89	10855.
94	11491.
99	12125.
104	12784.
109	13414.
114	13896.
119	14318.
124	14612.
129	14933.
134	15385.
139	16094.
144	16759.
148	17212.
153	17608.
158	17992.
163	18616.
168	19301.
173	20150.
178	21212.
183	22319.
188	22893.
192	23500.



HARPOON MISSILE CANISTER VERSION

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	88.12	
	CTR	166.00	
	AFT	189.12	
TRANSVERSE SHOCK FREQUENCY-HIGH TEMPERATURE		13.62	HZ
LOW TEMPERATURE		13.62	HZ
IMPACT VELOCITY		4.33	FPS

RESULTS

AT LOW TEMPERATURE

DECELERATION		11.51	G
DYNAMIC SUPPORT REACTIONS	FWD	14790.57	LBS
	CTR	-1072.73	LBS
	AFT	3721.88	LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-242384.69	IN-LBS
	CTR	44092.59	IN-LBS
	AFT	-551.31	IN-LBS

AT HIGH TEMPERATURE

DISPLACEMENT	0.61	INS

REMARKS: IMPACT VELOCITY EQUIVALENT NOT ACTUAL SEE TEXT
HIGH TEMP = LOW TEMP = 70°F

TABLE A-12

RESPONSE TO TRANSVERSE 15G, 18MS HALF SINE SHOCK SUMMARY

IS IN	MOM IN-LBS
0	0.
5	0.
10	0.
15	0.
20	-121.
25	-475.
30	-5226.
35	-10112.
40	-16202.
45	-24410.
49	-34885.
54	-48167.
59	-66473.
64	-89993.
69	-115588.
74	-143419.
79	-175830.
84	-211985.
88	-242385.
94	-204396.
99	-174351.
104	-146623.
109	-121992.
114	-98553.
119	-77738.
124	-57300.
129	-38659.
134	-20677.
139	-5244.
144	7346.
148	17976.
153	27404.
158	34918.
163	41851.
166	44092.
173	37971.
178	32043.
183	17888.
189	-551.
193	-0.

FIGURE A-17

RESPONSE TO TRANSVERSE 15G,18MS HALF SINE SHOCK
DYNAMIC BENDING MOMENTS

```
************************************************************************
*                                                                      *
*                                                                      *
*                                                                      *
*            HARPOON MISSILE CANISTER VERSION                          *
*                                                                      *
*                                                                      *
* INPUT PARAMETERS                                                     *
* ----------------                                                     *
*                                                                      *
*                                                                      *
*                                                                      *
*                                                                      *
*   SUPPORT LOCATIONS(IS)           FWD               88.12            *
*                                   CTR              166.00            *
*                                   AFT              189.12            *
*   VERTICAL SHOCK FREQ                                6.81 HZ         *
*   DROP HEIGHT                                        2.55 INS        *
*   WEIGHT OF THE CONTAINER SHELL                    500.00 LBS        *
*   WEIGHT OF CRADLE                                 917.50 LBS        *
*                                                                      *
*                                                                      *
* RESULTS                                                              *
* -------                                                              *
*                                                                      *
*                                                                      *
*  PRIMARY-                                                            *
*   DISPLACEMENT                                       1.27 INS        *
*   DECELERATION                                       6.01 G          *
*  REBOUND-                                                            *
*   DISPLACEMENT                                       0.22 INS        *
*   DECELERATION                                       1.02 G          *
*   DYNAMIC SUPPORT REACTIONS       FWD             7722.96 LBS        *
*                                   CTR             -560.13 LBS        *
*                                   AFT             1943.40 LBS        *
*   DYN BENDING MOM AT SUPPORTS-    FWD          -126562.29 IN-LBS     *
*                                   CTR            23023.15 IN-LBS     *
*                                   AFT             -287.87 IN-LBS     *
* REMARKS DROP HEIGHT EQUIVALENT NOT ACTUAL SEE TEXT                   *
*                                                                      *
*                                                                      *
*                                                                      *
************************************************************************
```

TABLE A-13

RESPONSE TO VERTICAL 15G,18MS HALF SINE SHOCK SUMMARY

FIGURE A-18

DYNAMIC BENDING MOMENTS
RESPONSE TO VERTICAL 15G,18MS HALF SINE SHOCK

IS IN	MOM IN-LBS
0	0.
5	0.
10	0.
15	0.
20	-63.
25	-248.
30	-2729.
35	-5280.
40	-8460.
45	-12746.
49	-18215.
54	-25151.
59	-34709.
64	-46990.
69	-60355.
74	-74887.
79	-91811.
84	-110689.
88	-126562.
94	-106726.
99	-91038.
104	-76560.
109	-63699.
114	-51460.
119	-40591.
124	-29920.
129	-20186.
134	-10797.
139	-2738.
144	3836.
148	9386.
153	14309.
158	18233.
163	21853.
166	23023.
173	19827.
178	16731.
183	9340.
189	-288.
193	-0.

Plot scale: 0 32000 64000 96000 128000

```
***********************************************************************
*                                                                     *
*                                                                     *
*                                                                     *
*            HARPOON MISSILE CANISTER VERSION                         *
*                                                                     *
*                                                                     *
* INPUT PARAMETERS                                                    *
* ----------------                                                    *
*                                                                     *
*                                                                     *
*   SUPPORT LOCATIONS(IS)          FWD              88.12             *
*                                  CTR             166.00             *
*                                  AFT             189.12             *
*   LONGITUDINAL SHOCK FREQUENCY-HIGH TEMPERATURE     6.81 HZ         *
*                                 LOW TEMPERATURE     6.81 HZ         *
*   IMPACT VELOCITY                                   4.52 FPS        *
*   NUMBER OF LONGITUDINAL BEARING RESTAINTS          1               *
*   LOCATION OF LONG BEARING RESTRAINTS(IS)         192.13            *
*   ECCENTRICITIES                                    5.75 INS        *
*                                                                     *
*                                                                     *
* RESULTS                                                             *
* -------                                                             *
*                                                                     *
*                                                                     *
*            AT LOW TEMPERATURE                                       *
*                                                                     *
*   DECELERATION                                      6.01 G          *
*   DYNAMIC SUPPORT REACTIONS      FWD             1263.03 LBS        *
*                                  CTR             2267.58 LBS        *
*                                  AFT            -2015.44 LBS        *
*   DYN BENDING MOM AT SUPPORTS-   FWD           -21058.62 IN-LBS     *
*                                  CTR             2118.66 IN-LBS     *
*                                  AFT            52312.93 IN-LBS     *
*                                                                     *
*   DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS                *
*   1ST BEARING RESTRAINT          52360.83          -0.00 IN-LBS     *
*                                                                     *
*                                                                     *
*            AT HIGH TEMPERATURE                                      *
*                                                                     *
*   DISPLACEMENT                                      1.27 INS        *
*                                                                     *
* REMARKS                                                             *
*       IMPACT VELOCITY EQUIVALENT NOT ACTUAL SEE TEXT                *
*       HIGH TEMP = LOW TEMP = 70°F                                   *
*                                                                     *
*                                                                     *
*                                                                     *
***********************************************************************
```

TABLE A-14

RESPONSE TO LONGITUDINAL 15G, 18MS HALF SINE SHOCK SUMMARY

FIGURE A-19

DYNAMIC BENDING MOMENTS
RESPONSE TO LONGITUDINAL 15G,18MS HALF SINE SHOCK

```
IS       MOM  0           14000         28000         42000         56000
IN      IN-LBS+-------------+-------------+-------------+-------------+
  0         0.+
  5         0.+
 10         0.+
 15         0.+
 20       -11.+
 25       -41.+
 30      -454.+
 35      -879.I+
 40     -1408.I+
 45     -2121.I +
 49     -3031.I  +
 54     -4185.I   +
 59     -5775.I     +
 64     -7819.I       +
 69    -10042.I         +
 74    -12460.I           +
 79    -15276.I              +
 84    -18417.I                 +
 88    -21059.I                    +
 94    -17888.I                 +
 99    -15386.I              +
104    -13086.I            +
109    -11055.I          +
114     -9127.I        +
119     -7428.I      +
124     -5761.I     +
129     -4250.I   +
134     -2797.I  +
139     -1565.I +
144      -580.I+
148       235.+
153       946.I+
158      1490.I+
163      1983.I +
166      2119.I +
173     18438.I                 +
178     29497.I                            +
183     39841.I                                       +
189     52313.I                                                   +
192     52361.I                                                   +
```

```
*****************************************************************
*                                                               *
*                                                               *
*                                                               *
*            AXIAL LOADS                                        *
*                                                               *
*                                                               *
*         HARPOON MISSILE CANISTER VERSION                      *
*                                                               *
*    DYNAMIC AXIAL LOADS AT LONGITUDINAL RESTRAINTS             *
*     1ST BEARING RESTRAINT            9106.23          LBS     *
*                                                               *
* REMARKS                                                       *
*                                                               *
*                                                               *
*                                                               *
*                                                               *
*****************************************************************
```

TABLE A-15

AXIAL LOAD SUMMARY
RESPONSE TO LONGITUDINAL 15G,18MS HALF SINE SHOCK

FIGURE A-20

DYNAMIC AXIAL LOADS
RESPONSE TO LONGITUDINAL 15G,18MS HALF SINE SHOCK

AXL LBS scale: 0, 3000, 6000, 9000, 12000

IS IN	AXL LBS
0	0.
5	3.
10	7.
15	10.
20	102.
25	268.
30	455.
35	604.
40	763.
45	975.
49	1249.
54	1686.
59	2166.
64	2524.
69	2872.
74	3210.
79	3575.
84	3934.
89	4206.
94	4453.
99	4698.
104	4954.
109	5198.
114	5385.
119	5548.
124	5662.
129	5786.
134	5962.
139	6236.
144	6494.
148	6669.
153	6823.
158	6972.
163	7214.
168	7479.
173	7808.
178	8220.
183	8649.
188	8871.
192	9106.

```
HARPOON MISSILE CANISTER VERSION

INPUT PARAMETERS
----------------

   SUPPORT LOCATIONS(IS)          FWD               88.12
                                  CTR              166.00
                                  AFT              189.12
   VERTICAL SHOCK FREQ                               6.81 HZ
   DROP HEIGHT                                      14.01 INS
   WEIGHT OF THE CONTAINER SHELL                   500.00 LBS
   WEIGHT OF CRADLE                                917.50 LBS

RESULTS
-------

 PRIMARY-
   DISPLACEMENT                                      2.65 INS
   DECELERATION                                     12.56 G
 REBOUND-
   DISPLACEMENT                                      0.45 INS
   DECELERATION                                      2.14 G
   DYNAMIC SUPPORT REACTIONS      FWD            16139.84 LBS
                                  CTR            -1170.59 LBS
                                  AFT             4061.41 LBS
   DYN BENDING MOM AT SUPPORTS-   FWD          -264496.24 IN-LBS
                                  CTR            48114.93 IN-LBS
                                  AFT             -601.60 IN-LBS
REMARKS DROP HEIGHT EQUIVALENT NOT ACTUAL SEE TEXT
```

TABLE A-16

RESPONSE TO VERTICAL 15G,35MS TRAPEZOIDAL SHOCK SUMMARY

FIGURE A-21

DYNAMIC BENDING MOMENTS
RESPONSE TO VERTICAL 15G,35MS TRAPEZOIDAL SHOCK

Scale: 0 — 67000 — 134000 — 201000 — 268000

IS IN	MOM IN-LBS
0	0.
5	0.
10	0.
15	0.
20	-132.
25	-518.
30	-5703.
35	-11034.
40	-17680.
45	-26637.
49	-38067.
54	-52561.
59	-72537.
64	-98203.
69	-126133.
74	-156503.
79	-191871.
84	-231324.
88	-264496.
94	-223042.
99	-190256.
104	-159999.
109	-133121.
114	-107543.
119	-84830.
124	-62527.
129	-42186.
134	-22563.
139	-5722.
144	8016.
148	19615.
153	29904.
158	38103.
163	45669.
166	48115.
173	41435.
178	34966.
183	19519.
189	-602.
193	-0.

```
*****************************************************************************
*                                                                           *
*                                                                           *
*                                                                           *
*                 HARPOON MISSILE CANISTER VERSION                          *
* INPUT PARAMETERS                                                          *
* ----------------                                                          *
*                                                                           *
*                                                                           *
*                                                                           *
*                                                                           *
*    SUPPORT LOCATIONS(IS)          FWD                   88.12             *
*                                   CTR                  166.00             *
*                                   AFT                  189.12             *
*    TRANSVERSE SHOCK FREQUENCY-HIGH TEMPERATURE          13.62 HZ          *
*                                LOW TEMPERATURE          13.62 HZ          *
*    IMPACT VELOCITY                                       4.77 FPS         *
*                                                                           *
*                                                                           *
* RESULTS                                                                   *
* -------                                                                   *
*                                                                           *
*                                                                           *
*               AT LOW TEMPERATURE                                          *
*                                                                           *
*    DECELERATION                                         12.68 G           *
*    DYNAMIC SUPPORT REACTIONS      FWD                16294.04 LBS         *
*                                   CTR                -1181.77 LBS         *
*                                   AFT                 4100.22 LBS         *
*    DYN BENDING MOM AT SUPPORTS-   FWD              -267023.27 IN-LBS      *
*                                   CTR                48574.63 IN-LBS      *
*                                   AFT                 -607.35 IN-LBS      *
*                                                                           *
*                                                                           *
*               AT HIGH TEMPERATURE                                         *
*                                                                           *
*    DISPLACEMENT                                          0.67 INS         *
*                                                                           *
* REMARKS: IMPACT VELOCITY EQUIVALENT NOT ACTUAL SEE TEXT                   *
*          HIGH TEMP = LOW TEMP = 70°F                                      *
*                                                                           *
*****************************************************************************
```

TABLE A-17

RESPONSE TO TRANSVERSE 9G,35MS TRAPEZOIDAL SHOCK SUMMARY

MOM scale: 0 — 67000 — 134000 — 201000 — 268000

IS IN	MOM IN-LBS
0	0.
5	0.
10	0.
15	0.
20	-133.
25	-523.
30	-5757.
35	-11140.
40	-17848.
45	-26891.
49	-38431.
54	-53063.
59	-73230.
64	-99141.
69	-127338.
74	-157998.
79	-193704.
84	-233534.
88	-267023.
94	-225173.
99	-192074.
104	-161527.
109	-134392.
114	-108571.
119	-85641.
124	-63125.
129	-42589.
134	-22779.
139	-5777.
144	8092.
148	19803.
153	30190.
158	38467.
163	46105.
166	48575.
173	41831.
178	35300.
183	19706.
189	-607.
193	-0.

FIGURE A-22

RESPONSE TO TRANSVERSE 9G,35MS TRAPEZIODAL SHOCK
DYNAMIC BENDING MOMENTS

```
                HARPOON MISSILE CANISTER VERSION

 INPUT PARAMETERS
 ----------------


    SUPPORT LOCATIONS(IS)            FWD                 88.12
                                     CTR                166.00
                                     AFT                189.12
    LONGITUDINAL SHOCK FREQUENCY-HIGH TEMPERATURE         6.81 HZ
                                    LOW TEMPERATURE       6.81 HZ
    IMPACT VELOCITY                                       3.78 FPS
    NUMBER OF LONGITUDINAL BEARING RESTAINTS              1
    LOCATION OF LONG BEARING RESTRAINTS(IS)             192.13
    ECCENTRICITIES                                        5.75 INS


 RESULTS
 -------


                AT LOW TEMPERATURE

    DECELERATION                                          5.02 G
    DYNAMIC SUPPORT REACTIONS        FWD               1266.66 LBS
                                     CTR               1878.70 LBS
                                     AFT              -1630.18 LBS
    DYN BENDING MOM AT SUPPORTS-     FWD             -21058.62 IN-LBS
                                     CTR               2400.70 IN-LBS
                                     AFT              43687.77 IN-LBS

    DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS
    1ST BEARING RESTRAINT            43735.67            -0.00 IN-LBS


                AT HIGH TEMPERATURE

    DISPLACEMENT                                          1.06 INS

 REMARKS
        IMPACT VELOCITY EQUIVALENT NOT ACTUAL SEE TEXT
        HIGH TEMP = LOW TEMP = 70°F
```

TABLE A-18

RESPONSE TO LONGITUDINAL 6G,35MS TRAPEZOIDAL SHOCK SUMMARY

FIGURE A-23

DYNAMIC BENDING MOMENTS
RESPONSE TO LONGITUDINAL 6G,35MS TRAPEZOIDAL SHOCK

```
IS     MOM  0                11000             22000             33000             44000
IN    IN-LBS+----------------+-----------------+-----------------+-----------------+
 0        0.+
 5        0.+
10        0.+
15        0.+
20      -11.+
25      -41.+
30     -454.I+
35     -879.I+
40    -1408.I +
45    -2121.I  +
49    -3031.I   +
54    -4185.I    +
59    -5775.I      +
64    -7819.I          +
69   -10042.I             +
74   -12460.I                 +
79   -15276.I                    +
84   -18417.I                         +
88   -21059.I                               +
94   -17867.I                         +
99   -15347.I                     +
104  -13029.I                 +
109  -10980.I              +
114   -9034.I          +
119   -7317.I        +
124   -5632.I      +
129   -4103.I    +
134   -2632.I  +
139   -1382.I +
144    -379.+
148     454.I+
153    1182.I +
158    1744.I +
163    2255.I  +
166    2400.I  +
173   15944.I                     +
178   25097.I                                    +
183   33534.I                                                 +
189   43688.I                                                                   +
192   43736.I                                                                   +
```

```
**************************************************************************
*                                                                        *
*                                                                        *
*                                                                        *
*              AXIAL LOADS                                               *
*                                                                        *
*                                                                        *
*          HARPOON MISSILE CANISTER VERSION                              *
*                                                                        *
*     DYNAMIC AXIAL LOADS AT LONGITUDINAL RESTRAINTS                     *
*      1ST BEARING RESTRAINT               7606.20           LBS         *
*                                                                        *
* REMARKS                                                                *
*                                                                        *
*                                                                        *
*                                                                        *
*                                                                        *
**************************************************************************
```

TABLE A-19

AXIAL LOAD SUMMARY
RESPONSE TO LONGITUDINAL 6G,35MS TRAPEZOIDAL SHOCK

FIGURE A-24

DYNAMIC AXIAL LOADS
RESPONSE TO LONGITUDINAL 6G,35MS TRAPEZOIDAL SHOCK

AXL 0 — 2000 — 4000 — 6000 — 8000

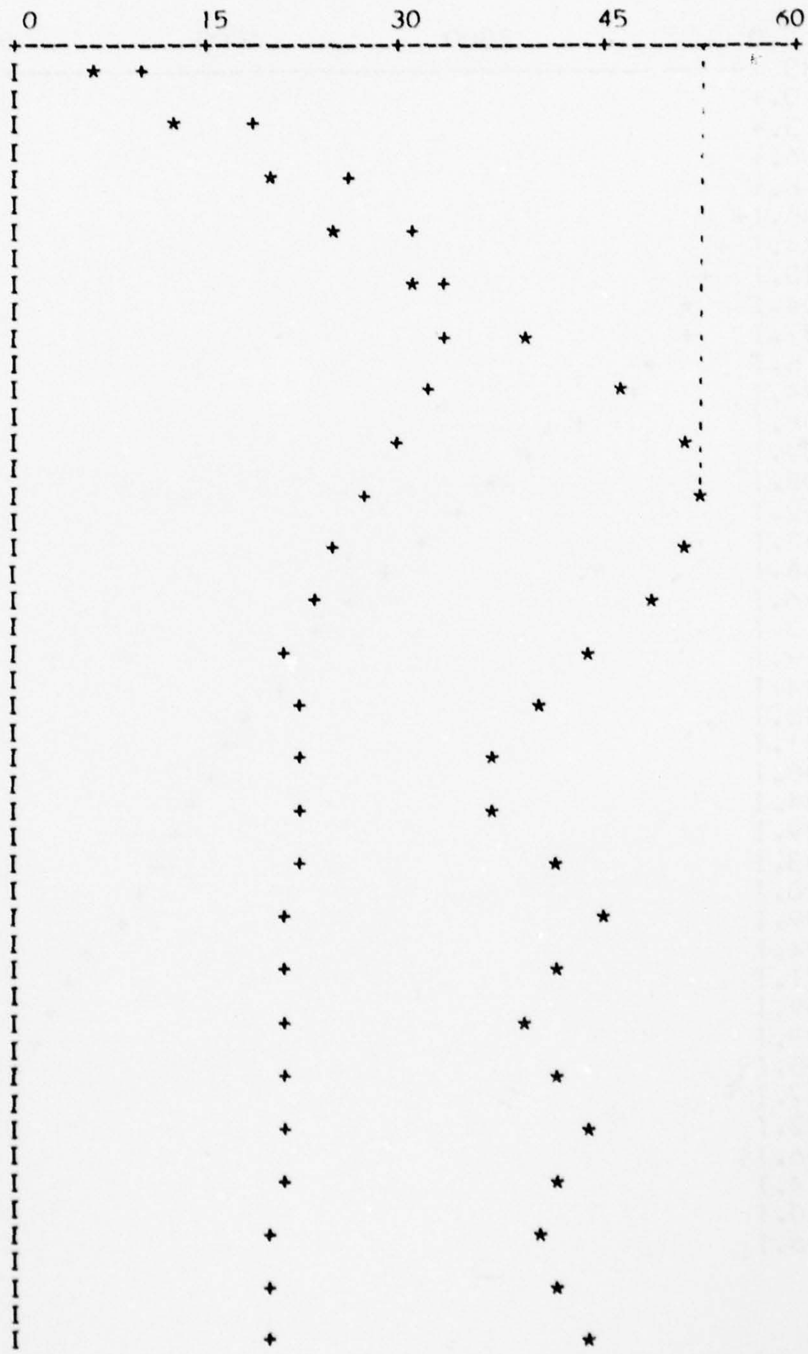
IS IN	AXL LBS
0	0.
5	3.
10	6.
15	8.
20	85.
25	224.
30	380.
35	504.
40	637.
45	815.
49	1044.
54	1408.
59	1809.
64	2108.
69	2399.
74	2682.
79	2986.
84	3286.
89	3513.
94	3719.
99	3924.
104	4138.
109	4341.
114	4498.
119	4634.
124	4729.
129	4833.
134	4980.
139	5209.
144	5424.
148	5571.
153	5699.
158	5823.
163	6025.
168	6247.
173	6522.
178	6866.
183	7224.
188	7410.
192	7606.

FIGURE A-25

COMPARISON OF 42G,25MS TPS (SPECIFICATION) TO 19.09G,64MS HALF SINE RESPONSE TO -20°F FORWARD EDGE ROTATIONAL DROP (RESPONSE)

SHOCK SPECTRUM
SPECIFICATION = *
RESPONSE = +

FREQ HZ	SPEC G	RESP G
2.	6.5	9.6
4.	12.8	18.4
6.	19.0	25.5
8.	24.9	30.3
10.	30.3	32.8
14.	39.7	33.6
18.	46.7	31.9
22.	51.0	29.5
26.	52.5	27.1
30.	51.8	24.8
34.	48.4	22.9
38.	44.2	21.1
42.	40.0	21.6
46.	37.3	22.3
50.	36.7	22.4
60.	42.0	21.7
70.	45.8	20.5
80.	42.0	21.0
90.	39.0	20.8
100.	42.0	20.3
110.	44.4	20.5
120.	42.0	20.4
130.	39.9	20.1
140.	42.0	20.1
150.	43.7	20.1



```
*****************************************************************************
*                                                                           *
*                              FIGURE A-26                                  *
*                                                                           *
*    COMPARISON OF 42G,25MS TPS (SPECIFICATION) TO RESPONSE TO              *
*           TRANSVERSE 9G,35MS TRAPEZOIDAL SHOCK (RESPONSE)                 *
*                                                                           *
*****************************************************************************

                                  SHOCK SPECTRUM
                                 SPECIFICATION = *
                                       RESPONSE = +

FREQ  SPEC  RESP  0              15             30             45             60
 HZ     G     G   +--------------+--------------+--------------+-------+------+
   2.   6.5   4.3 I   + *
                  I
   4.  12.8   8.4 I       +    *
                  I
   6.  19.0  12.1 I           +      *
                  I
   8.  24.9  15.2 I              +         *
                  I
  10.  30.3  17.7 I                 +           *
                  I
  14.  39.7  20.4 I                   +                   *
                  I
  18.  46.7  20.9 I                    +                         *
                  I
  22.  51.0  20.1 I                   +                              *
                  I
  26.  52.5  18.8 I                  +                                 *
                  I
  30.  51.8  17.3 I                +                                  *
                  I
  34.  48.4  16.0 I               +                               *
                  I
  38.  44.2  14.8 I              +                            *
                  I
  42.  40.0  13.9 I             +                         *
                  I
  46.  37.3  13.4 I            +                       *
                  I
  50.  36.7  13.4 I            +                       *
                  I
  60.  42.0  13.7 I             +                           *
                  I
  70.  45.8  13.3 I            +                                *
                  I
  80.  42.0  13.1 I            +                            *
                  I
  90.  39.0  13.0 I            +                         *
                  I
 100.  42.0  12.9 I            +                            *
                  I
 110.  44.4  12.8 I            +                              *
                  I
 120.  42.0  12.8 I            +                            *
                  I
 130.  39.9  12.8 I            +                          *
                  I
 140.  42.0  12.8 I            +                            *
                  I
 150.  43.7  12.8 I            +                              *
```

FIGURE A-27

COMPARISON OF 42G,25MS TPS (SPECIFICATION) TO RESPONSE TO LONGITUDINAL 25G,25MS HALF SINE SHOCK AT -20°F (RESPONSE)

SHOCK SPECTRUM
SPECIFICATION = *
RESPONSE = +

0 15 30 45 60

FREQ HZ	SPEC G	RESP G
2.	6.5	8.0
4.	12.8	15.3
6.	19.0	21.0
8.	24.9	24.7
10.	30.3	26.5
14.	39.7	26.8
18.	46.7	25.3
22.	51.0	23.2
26.	52.5	21.1
30.	51.8	19.3
34.	48.4	17.6
38.	44.2	16.3
42.	40.0	15.5
46.	37.3	15.9
50.	36.7	16.0
60.	42.0	15.7
70.	45.8	15.8
80.	42.0	15.7
90.	39.0	15.5
100.	42.0	15.6
110.	44.4	15.5
120.	42.0	15.6
130.	39.9	15.6
140.	42.0	15.5
150.	43.7	15.5

APPENDIX B

HARPOON MISSILE CANISTER

COMPUTER OUTPUT

FLAT DROP- HARPOON MISSILE CANISTER

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	80.52
	AFT	158.39
VERTICAL SHOCK FREQ		6.81 HZ
DROP HEIGHT		18.00 INS
WEIGHT OF THE CONTAINER SHELL		500.00 LBS
WEIGHT OF CRADLE		427.20 LBS

RESULTS

PRIMARY-		
DISPLACEMENT		2.98 INS
DECELERATION		14.09 G
REBOUND-		
DISPLACEMENT		0.51 INS
DECELERATION		2.40 G
DYNAMIC SUPPORT REACTIONS	FWD	21418.74 LBS
	AFT	6842.48 LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-100807.82 IN-LBS
	AFT	-139045.27 IN-LBS

REMARKS

TABLE B-1

FLAT DROP SUMMARY

FIGURE B-1

DYNAMIC BENDING MOMENTS
18 INCH FLAT DROP

Scale: 0 — 35000 — 70000 — 105000 — 140000

IS IN	MOM IN-LBS
0	0.
5	-1295.
10	-4226.
15	-7185.
19	-10905.
24	-14710.
29	-19480.
34	-24697.
39	-30561.
44	-36623.
48	-43276.
53	-50183.
58	-58135.
63	-66454.
68	-75251.
73	-84416.
77	-94002.
81	-100808.
87	-99871.
92	-99758.
97	-99954.
102	-100686.
106	-101671.
111	-103248.
116	-105022.
121	-107446.
126	-110009.
131	-113277.
135	-116630.
140	-120744.
145	-124885.
150	-129845.
155	-134804.
158	-139045.
165	-101547.
169	-73068.
174	-44723.
179	-17472.
184	-1865.
189	0.

```
END IMPACT- HARPOON MISSILE CANISTER

INPUT PARAMETERS
----------------

   SUPPORT LOCATIONS(IS)              FWD                              80.52
                                      AFT                             158.39
   LONGITUDINAL SHOCK FREQUENCY-HIGH TEMPERATURE                       6.46 HZ
                                    LOW TEMPERATURE                    7.76 HZ
   IMPACT VELOCITY                                                    10.00 FPS
   NUMBER OF LONGITUDINAL BEARING RESTAINTS                            1
   LOCATION OF LONG BEARING RESTRAINTS(IS)                           158.39
   ECCENTRICITIES                                                     11.95 INS


RESULTS
-------


             AT LOW TEMPERATURE (-20°F)

   DECELERATION                                                      15.14 G
   DYNAMIC SUPPORT REACTIONS          FWD                          6179.13 LBS
                                      AFT                         -4173.73 LBS
   DYN BENDING MOM AT SUPPORTS-       FWD                         -7153.27 IN-LBS
                                      AFT                        352950.66 IN-LBS

   DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS
   1ST BEARING RESTRAINT            352950.66                              IN-LBS

   DYNAMIC AXIAL LOADS AT LONGITUDINAL RESTRAINTS
   1ST BEARING RESTRAINT             30356.89                                 LBS



             AT HIGH TEMPERATURE (140°F)

   DISPLACEMENT                                                       2.96 INS

REMARKS
```

TABLE B-2

END IMPACT SUMMARY

FIGURE B-2

DYNAMIC BENDING MOMENTS
10 FPS END IMPACT

Scale: 0 179000 358000 537000 716000

IS IN	MOM IN-LBS
0	0.
5	-92.
10	-300.
15	-510.
19	-774.
24	-1044.
29	-1382.
34	-1752.
39	-2169.
44	-2599.
48	-3071.
53	-3561.
58	-4125.
63	-4716.
68	-5340.
73	-5990.
77	-6670.
81	-7153.
87	23535.
92	46087.
97	68617.
102	91109.
106	113582.
111	136014.
116	158432.
121	180804.
126	203166.
131	225477.
135	247783.
140	270035.
145	292285.
150	314476.
155	336668.
158	352950.
165	-7206.
169	-5185.
174	-3174.
179	-1240.
184	-132.
189	0.

FIGURE B-3

DYNAMIC AXIAL LOADS
10 FPS END IMPACT

```
IS        AXL 0           7000          14000          21000          28000
IN        LBS +--------------+--------------+--------------+--------------+
  0         0.+
  5       547.I+
 10       651.I+
 15       742.I+
 19       833.I +
 24       924.I +
 29      1138.I +
 34      1230.I +
 39      1322.I  +
 44      1412.I  +
 48      1501.I  +
 53      1588.I  +
 58      1811.I   +
 63      1901.I   +
 68      1992.I   +
 73      2083.I   +
 77      2415.I    +
 82      3035.I     +
 87      3472.I      +
 92      3563.I      +
 97      3654.I      +
102      3745.I      +
106      3836.I       +
111      3926.I       +
116      4017.I       +
121      4108.I       +
126      4199.I       +
131      4290.I        +
135      4381.I        +
140      4471.I        +
145      4562.I        +
150      4653.I        +
155      4744.I        +
158     30357.I                                                             +
165    -24527.I                                                    +
169    -24356.I                                                    +
174    -24214.I                                                   +
179    -24007.I                                                   +
184    -14809.I                               +
189       -73.+
```

```
 ROTATIONAL EDGEWISE DROP
         HARPOON MISSILE CANISTER

INPUT PARAMETERS
----------------

   HALF MOUNT SPACING                                  65.00 INS
   SUPPORT LOCATIONS(IS)              FWD              80.52
                                      AFT             158.39
   OVERALL CONTAINER LENGTH                           217.00 INS
   ITEM PITCH MOMENT OF INERTIA                     14574.80 IN-LB-SECSQ
   DISTANCE ITEM C.G. TO CONT BASE                     25.19 INS
   DISTANCE ITEM C.G. TO CONT FORWARD END             112.25 INS
   DROP HEIGHT                                         18.00 INS
   VERTICAL FREQUENCY-LOW TEMPERATURE                   7.76 HZ
   VERTICAL FREQUENCY-HIGH TEMPERATURE                  6.46 HZ
   LOCATION FOR DEC CALCULATIONS-FORWARD                2.02 (IS)
   LOCATION FOR DEC CALCULATIONS-AFT                  184.20 (IS)
   LOCATION FOR DSPL CALCULATIONS-FORWARD               2.02 (IS)
   LOCATION FOR DSPL CALCULATIONS-AFT                 184.20 (IS)
   CRADLE WEIGHT                                      427.10 LBS
   CRADLE C.G. LOCATION                               100.39 (IS)
   CRADLE PITCH MOMENT OF INERTIA                    4021.86 IN-LB-SECSQ

RESULTS
-------
   TOTAL WEIGHT OF ITEM AND CRADLE                   2432.50 LBS
   TOTAL PITCH MOMENT OF INERTIA                    18597.60 IN-LB-SECSQ
   TOTAL C.G. IS LOCATED AT                            99.55 (IS)

             AT LOW TEMPERATURE (-20°F)

 FORWARD EDGE DROP
   MAXIMUM DECELERATION AT(IS)      2.02                    19.22 G
   DYNAMIC SUPPORT REACTIONS        FWD                  19462.03 LBS
                                    AFT                   -958.35 LBS
   DYN BENDING MOM AT SUPPORTS-     FWD               -124657.70 IN-LBS
                                    AFT                 -7547.32 IN-LBS

 AFT EDGE DROP
   MAXIMUM DECELERATION AT(IS) 184.20                       18.20 G
   DYNAMIC SUPPORT REACTIONS        FWD                   9343.47 LBS
                                    AFT                  10023.56 LBS
   DYN BENDING MOM AT SUPPORTS-     FWD                 -11547.55 IN-LBS
                                    AFT                -177181.93 IN-LBS


             AT HIGH TEMPERATURE (140°F)

   FWD EDGE DROP DISPLACEMENT AT(IS)  2.02                   3.16 INS
   AFT EDGE DROP DISPLACEMENT AT(IS)184.20                   3.05 INS
```

TABLE B-3

ROTATIONAL EDGEWISE DROP SUMMARY

FIGURE B-4

PLOT OF DECELERATION AT ITEM STATIONS
FOR HALF-MOUNTSPACING 65 INCHES
FORWARD AND AFT DROPS AT -20°F
FORWARD DROP = +
AFT DROP = *

IS IN	FDC G	ADC G
0	19.43	-0.35
5	18.93	0.14
10	18.43	0.63
15	17.94	1.11
19	17.44	1.60
24	16.94	2.09
29	16.45	2.58
34	15.95	3.06
39	15.45	3.55
44	14.96	4.04
48	14.46	4.52
53	13.96	5.01
58	13.47	5.50
63	12.97	5.99
68	12.47	6.47
73	11.98	6.96
77	11.48	7.45
82	10.98	7.93
87	10.49	8.42
92	9.99	8.91
97	9.49	9.40
102	9.00	9.88
106	8.50	10.37
111	8.00	10.86
116	7.51	11.34
121	7.01	11.83
126	6.51	12.32
131	6.02	12.80
135	5.52	13.29
140	5.02	13.78
145	4.53	14.27
150	4.03	14.75
155	3.54	15.24
160	3.04	15.73
165	2.54	16.21
169	2.05	16.70
174	1.55	17.19
179	1.05	17.68
184	0.56	18.16
189	0.06	18.65

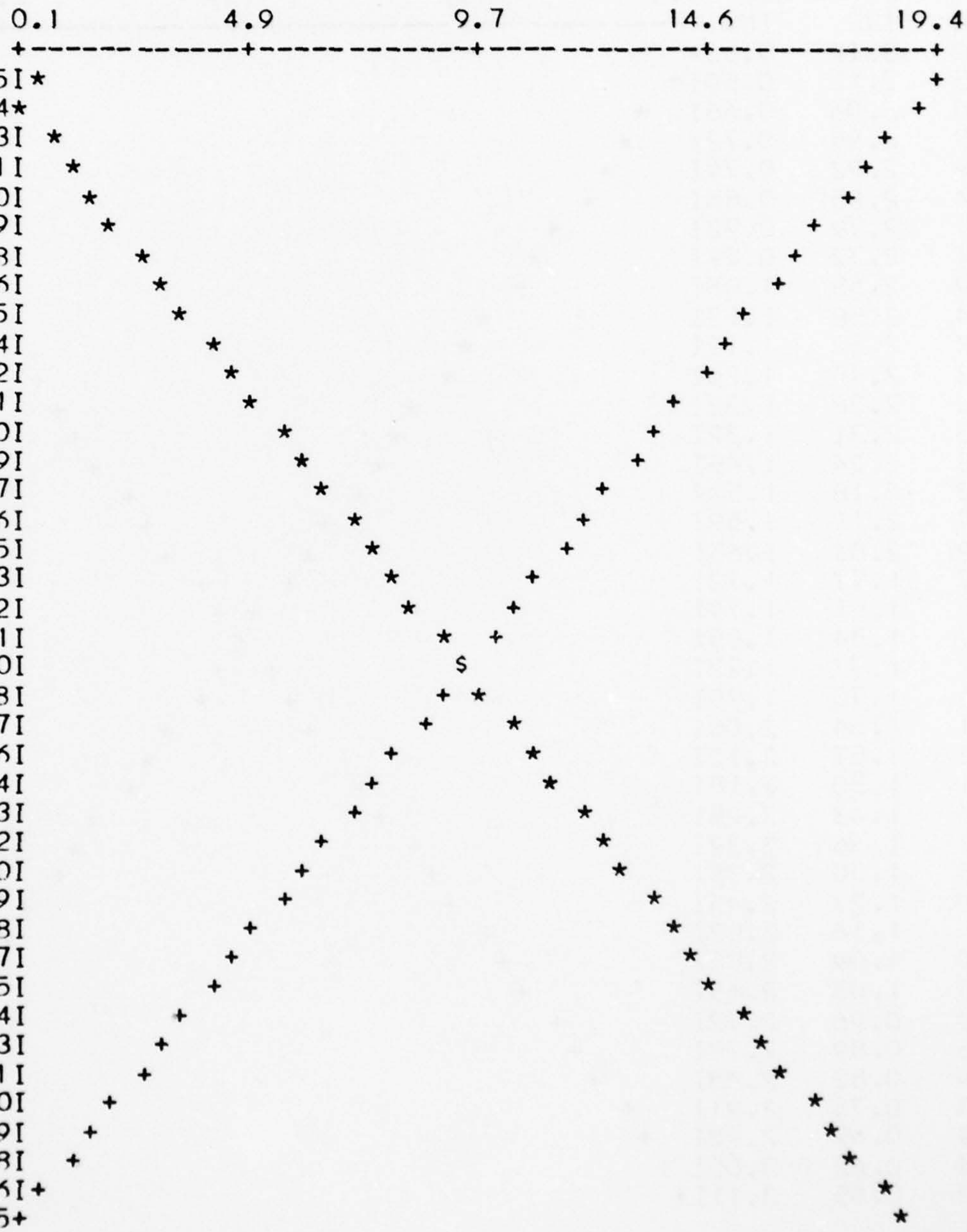
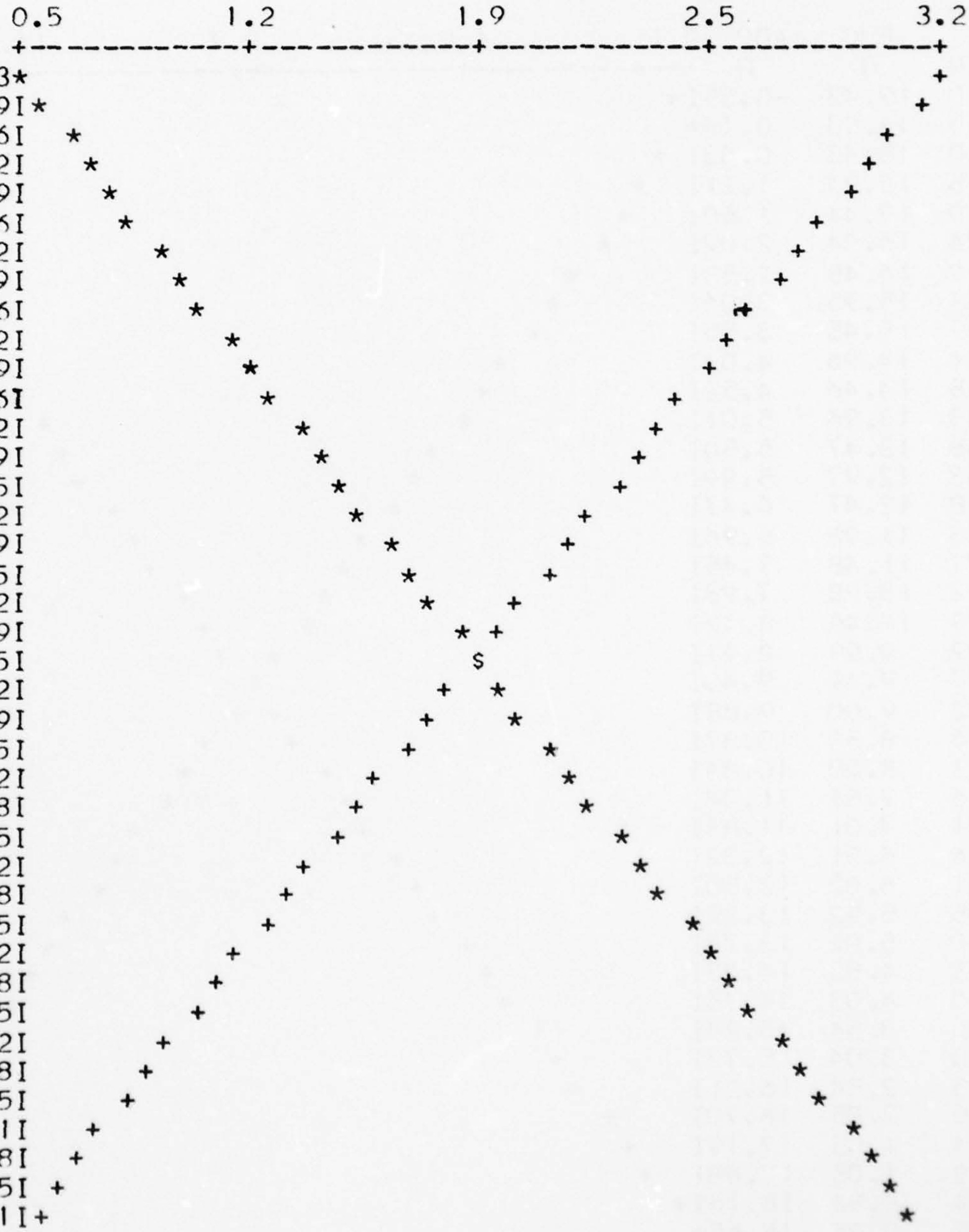


FIGURE B-5

PLOT OF DISPLACEMENT AT ITEM STATIONS
FOR HALF-MOUNTSPACING 65 INCHES
FORWARD AND AFT DROPS AT 140°F
FORWARD DROP = +
AFT DROP = *

IS IN	FDS INS	ADS INS
0	3.19	0.53
5	3.12	0.59
10	3.06	0.66
15	2.99	0.72
19	2.92	0.79
24	2.85	0.86
29	2.79	0.92
34	2.72	0.99
39	2.65	1.06
44	2.58	1.12
48	2.52	1.19
53	2.45	1.26
58	2.38	1.32
63	2.31	1.39
68	2.24	1.45
73	2.18	1.52
77	2.11	1.59
82	2.04	1.65
87	1.97	1.72
92	1.91	1.79
97	1.84	1.85
102	1.77	1.92
106	1.70	1.99
111	1.64	2.05
116	1.57	2.12
121	1.50	2.18
126	1.43	2.25
131	1.36	2.32
135	1.30	2.38
140	1.23	2.45
145	1.16	2.52
150	1.09	2.58
155	1.03	2.65
160	0.96	2.72
165	0.89	2.78
169	0.82	2.85
174	0.76	2.91
179	0.69	2.98
184	0.62	3.05
189	0.55	3.11



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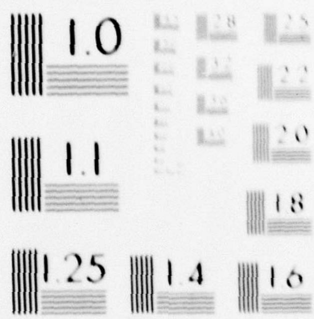

MICROCOPY RESOLUTION TEST CHART
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FIGURE B-6

DYNAMIC BENDING MOMENTS
18 INCH FORWARD EDGE ROTATIONAL DROP

IS IN	DYM IN-LBS
0	0.
5	-1770.
10	-5752.
15	-9771.
19	-14757.
24	-19849.
29	-26093.
34	-32867.
39	-40369.
44	-48093.
48	-56439.
53	-65051.
58	-74690.
63	-84688.
68	-95119.
73	-105882.
77	-116997.
81	-124658.
87	-112315.
92	-103666.
97	-95229.
102	-87160.
106	-79247.
111	-71697.
116	-64253.
121	-57161.
126	-50134.
131	-43438.
135	-36774.
140	-30412.
145	-24058.
150	-17969.
155	-11879.
158	-7547.
165	-5308.
169	-3745.
174	-2205.
179	-779.
184	-24.
189	-0.

FIGURE B-7

DYNAMIC BENDING MOMENTS
18 INCH AFT EDGE ROTATIONAL DROP

Scale: 0 — 45000 — 90000 — 135000 — 180000

IS IN	DYM IN-LBS
0	0.
5	17.
10	32.
15	46.
19	-2.
24	-58.
29	-265.
34	-546.
39	-972.
44	-1442.
48	-2089.
53	-2811.
58	-3912.
63	-5149.
68	-6596.
73	-8204.
77	-10028.
81	-11548.
87	-22411.
92	-30745.
97	-39280.
102	-48167.
106	-57237.
111	-66737.
116	-76393.
121	-86567.
126	-96862.
131	-107770.
135	-118756.
140	-130458.
145	-142188.
150	-154746.
155	-167303.
158	-177182.
165	-129599.
169	-93326.
174	-57208.
179	-22430.
184	-2453.
189	0.